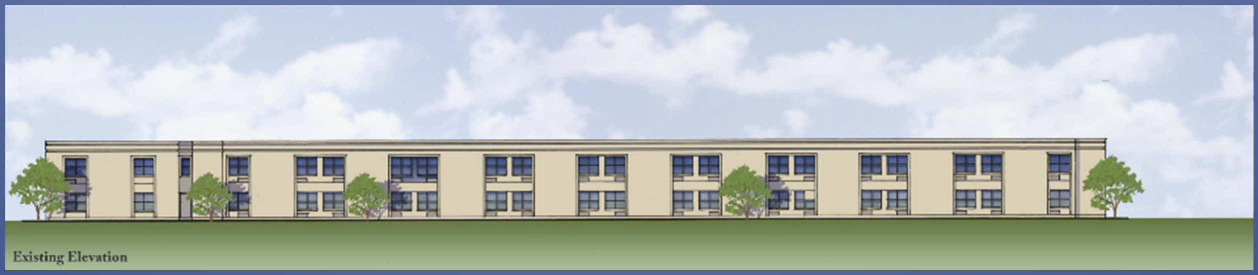
Senior Thesis Report

April 4th, 2012



Masonic Village at Sewickley

Sewickley, PA

Jason Drake

Construction Option

Advisor: Jim Faust

Masonic Village at Sewickley

Sewickley, PA

Courtesy of: Reese, Lower, Patrick, & Scott, LTD.

MEP

Cooling Tower:	90,000 CFM
Boilers:	3 Natural Gas Boilers
	1 – WSHP (1,9680 MBH)
	2 – Hot Water (1,680 MBH)
Condenser Pumps:	2 Pumps (826 GPM)
Heat Recovery:	2 Units (2,500 CFM)
Electrical System:	480/277V
	3 Φ, 4 Wire
Utility Feed:	15 kV
Generator:	800 kW
Fire Suppression:	Wet Pipe Sprinkler System

Project Overview

Owner:	Masonic Villages of Pennsylvania
CM:	Weber Murphy Fox
Architect:	Reese, Lower, Patrick, & Scott
Engineers:	Macintosh Engineering, Alderson Engineering, Gateway Engineering
Building Type:	Retirement Home/Health Care
Total Height:	3 Stories
Project Cost:	$22.8 Million
Duration:	Sept. 13, 2012 – Sept. 27, 2012
Address:	1000 Masonic Dr.
	Sewickley, PA 15143

Construction

Project Delivery:	GMP
Enclosure:	Brick Veneer (3-5/8" x 7-5/8")
	Asphalt Shingles
Occupancy:	128 Beds
New Construction:	66,455 SF
Renovation Work:	40,000 SF
Project Phasing:	*Phase 1* – Site Development
	Phase 2 – New Additions
	Phase 3 – Connect Additions
	Phase 4 – Heavy Renovations
	Phase 5 – Light Renovations

Structure

Foundation:	Caissons
	Grade Beams
	Spread Footings
CIP Concrete:	4" Slabs-on-Grade
	2" Topping Slabs
	1st Floor Form Walls
Precast Concrete:	Solid Core Concrete Planking
Masonry:	CMU Bearing Walls (8"x16")
Roof:	Wood Trusses
	Wood Sheathing

Jason M. Drake
Architectural Engineering | Construction Option
http://www.engr.psu.edu/ae/thesis/portfolios/2012/JMD5306/index.html

Executive Summary

Masonic Village at Sewickley is a campus dedicated to elderly retirement facilities. In September of 2010, the client chose to double the number of beds spaces in their existing nursing facility from 64 to 128 beds. Expansions lead to 66,455 SF of additions as well as 40,000 SF of major renovations. The final report begins by detailing in-depth *technical research* on the overall project. A thorough knowledge of the building lead to the following 4 research analyses, which are intended to strengthen the final quality of the building and construction processes:

Analysis #1: Masonry Acceleration

Masonry is undoubtedly one of the most critical factors driving the project's schedule. Finding ways to speed up masonry construction provides huge advantages for the project schedule. Analysis #1 outlines 3 possible alternatives for achieving this goal; adjusting critical path elements, mortar mixing procedures, and scaffolding options. Removing floor slabs from being an integral part of the wall was indisputably the largest accelerator for masonry at a savings of 26 days. The sum of all three masonry acceleration techniques provided a grand total time savings of 36.1 work days.

Analysis #2: Façade Dimensioning

The outer perimeter of the building's façade is made up of 116 dimensional elements. 64 of these "walls" were simply not designed to be compatible with 16" increments friendly to masonry work. Adjusting all measurements on a scale of inches, such that no block needed to be cut, created a huge cost reduction. Savings' were researched in material waste, time, and manpower. Small changes in designed wall lengths contributed a cost savings of $74,394.

Analysis #3: Value Engineered Façade

With so much brick being utilized on site, the implementation of brick block provides an opportunity to nearly cut masonry costs in half. Brick blocks are CMU's embossed with a running bond pattern of standard 8" brick. The pattern provides the illusion of an actual "brick" façade and eliminates the need for veneer. Although higher unit costs, coloring options, and insulation are all more expensive, savings benefits of having no veneer far outweigh these expenses in the grand scheme of construction. Even after such additional expenses have been deducted, a brick block façade would ultimately save the project team $249,200.

Analysis #4: Masonry Sustainability

The abundance of masonry on site ultimately lead to seeking methods of utilizing the material from a sustainability standpoint. The facility has already earned a rating of LEED Silver with a total of 55 points. Earning just 5 additional points would upgrade the project's status to LEED Gold. Masonry has the ability to earn LEED points in 3 different categories; sustainable sites, energy and atmosphere, and materials and resources. Various suggested techniques added 1 LEED point in each of the first two categories and 3 in the final one. Employing the techniques outlined in Analysis #4 would not only earn 5 additional LEED points for the project but also transform the building from LEED Silver to LEED Gold.

Acknowledgements

Academic Acknowledgements:

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Dr. Craig Dubler

Professor Jim Faust

Industry Acknowledgements:

(Weber Murphy Fox, Inc.)

(Masonic Villages of Pennsylvania)

Special Thanks:

Tony Grace, Project Manager

Kim Jeffreys, Project Executive

Patty Downey, Project Coordinator

Steve Burdick, Site Superintendent

Masonic Villages of Pennsylvania

PACE Industry Members

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Project Overview

Masonic Villages of Pennsylvania is an institution that has been in business for over 130 years. Committed to satisfying the needs of their clients, a vision of excellence is the driving force behind the longevity of the company. Over the course of the last century the organization has established 5 separate campuses throughout the state of Pennsylvania. Campus locations include Lafayette Hill, Elizabethtown, Warminster, Sewickley, and their recently founded Dallas location.

The history of Masonic Village at Sewickley is relatively young. The organization has occupied the property since 1999 when the campus was purchased from the Valley Care Association. Masonic Village has long envisioned establishing a superior retirement care community. Quality service for its residents is of top priority. Since the possession of the property, a 60 apartment personal care facility and a 227 unit retirement living apartment building with 43 villas has been constructed. Each expansion indirectly proves their exceptional ability to satisfy the needs of residents and their families. In September of 2010, Masonic Village has once again chosen to expand, with two 30,000 SF additions to their retirement living center.

The time of construction has been slated from September 13, 2010 – September 27, 2012. However, weather and other external factors may pose an issue with reaching the completion date on time. As the construction manager of the project, it is up to Weber Murphy Fox to adequately oversee the project and keep things on schedule. The total cost of construction for Masonic Village at Sewickley is roughly $22.8 million and was delivered to the owner through a GMP contract. The structure contains two floors completely above grade with one much smaller floor partially submerged in the hillside. The primary function of the building is to serve as a retirement home/health care facility for the greater Sewickley area. Construction will expand across roughly 100,000 SF of building area. However only 66,455 SF will be new construction, whereas the remaining 40,000 SF will be dedicated to interior renovations of the existing building.

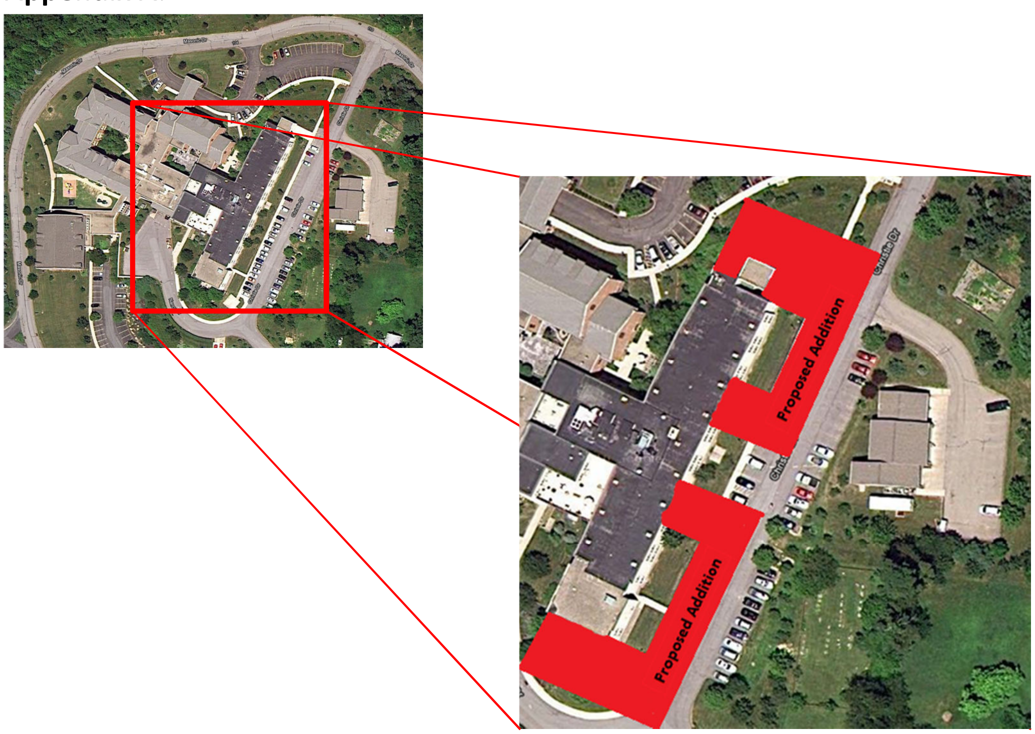
The overall purpose of the project is to expand the total number of bed spaces within the facility. The existing assisted living center has a maximum capacity of 64 residents. Upon completion of the additions and renovations, the allowable occupancy will be doubled in size and care will be provided for up to 128 patients. Given that the additions will house a total of 96 bedrooms, many of the existing resident rooms will be demolished during renovations and replaced with lounges, dining, and social gathering spaces to better suit the needs of residents.

Existing Conditions

The primary function of the building is to serve as a retirement home/health care facility. Construction on Masonic Village at Sewickley will expand across roughly 100,000 SF of building area. Nonetheless, only 66,455 SF will be new construction, whereas the remaining 40,000 SF will be dedicated to interior renovations of the existing building. The structure contains two floors completely above grade with one much smaller floor partially submerged in a hillside.

The project design team created a plan that not only fit the owner's needs but also allowed for the best ease of flow between interrelated spaces. They did a great job of keeping resident rooms in more private areas of the building, while maintaining public areas on the building's north side. The duration of construction has been slated from September 13, 2010 – September 27, 2012. However, weather and other external factors may pose issues with reaching the completion date on time. As the construction manager of the project, it is up to Weber Murphy Fox to adequately oversee the project and keep things on schedule.

Arial images of the site as well as proposed areas of construction can be viewed in Figure 1. It is important for the CM to have a solid understanding of the site and its surroundings in order for the job to run smoothly. Nothing is more important for the construction phase than proper planning. A more comprehensive graphic of underground utility locations is detailed in **Appendix A**.



(**Figure 1:** Arial View of Site)

- Courtesy of Google Maps

Local Conditions

Masonic Village at Sewickley is located at 1000 Masonic Drive in Sewickley, PA. The size of the property itself is approximately 54 acres, located in the peaceful hills of the Sewickley Valley. The skilled care facility itself will be comprised of two wings connected to the existing building at two separate points. The additions will provide an extra 64 bed spaces to the facility.

With the relocation of the existing parking lot and the addition of another, laborers are allotted 50 spaces near the site. As the crew begins to reach its maximum work force, parking for laborers may become somewhat tight. In a typical day there are only 30-35 personnel on site. Nonetheless, the peak work force is expected to top out at about 70 people. As a result of the construction, health care employees at Masonic Village are expected to park in lots further away than they otherwise typically would. Parking for the nursing facility is oriented around the north and west sides of the site, with plenty of yard space and small wooded areas located in close proximity.

Given the name of the facility, “Masonic” Village, the preferred means of construction throughout the complex is masonry. Buildings in the surrounding area as well as the existing portion of the structure are typically CMU load bearing walls covered with a brick veneer. Tipping fees on site are about $54 per ton and no effort has been put forth to implement any sort of organized recycling plan.

Zoning for Masonic Village at Sewickley is classified under multifamily residential. Given the size of the site, developers had virtually no problem keeping building lines well within the required setbacks of 15’ during the design development process. Most setbacks reach up to one hundred feet or more. Furthermore, the excessive size of the property made it very easy to satisfy zoning requirements in regards to the desired number of parking spaces for the facility.

According to code, each resident is to be provided with an exterior window. Since each wing laps back along the south wall, courtyards were added as a buffer, providing light-wells for individuals residing at the building’s core. This technique will provide natural light to all rooms that remain in the original half of the structure.

The geotechnical report presented a number of different findings. The topsoil is a medium damp, tan organic clayey silt. At depth of three feet, the soil becomes a light brown silt with traces of stiff rock fragments. Continuing deeper down the boring sample, light brown siltstone is evident at approximately eight feet. From eight to twenty feet on the boring sample, the soil is a gray and brown sandstone with angular joints and frequently soft seams. Ground water was not present in any test boring and is assumed to be much deeper than twenty feet.

Client Information

Cost is one of the most critical factors to the owner. Although they were provided a GMP by the construction manager, it is important for the project team to aim for the lowest possible price without sacrificing the building's quality. Savings sharing clauses provide added incentive for the CM to satisfy the needs of the owner. Schedule is of much lesser concern to the client. There are no immediate penalties to the construction manager for not completing the project on time. Nonetheless, the project team is dedicated to keeping the project within the confines of their projected schedule and proving to the owner that they do not lack capability in any aspect of their work.

Safety is another huge concern of the owner, not only for workers on site but also for their faculty and residents. With many resident rooms located directly adjacent to where the additions are being erected, precautionary measures such as maintaining adequate egress and monitoring construction dust and debris is of utmost importance. Noise is of further concern to the owner. Construction of the additions and renovations is only allowed to occur during certain hours of the day, so as to reduce the amount of disruption to resident life.

The intricate sequencing process is also of much interest to the owner due to the fact that residents will need to be shifted around as the project progresses through its phases. After the completion of the additions, residents are to be shifted such that their existing rooms can be demolished and relocated to a different area of the building. The first concern of the owner is that health care personnel are easily able to access patient rooms at all times. Secondly, with the demolition of existing rooms it is critical for sequencing to occur in such as fashion that a minimum of 64 bed spaces are maintained at all times. Keeping the owner up to date with each of these issues plays a key role in overall client satisfaction of the project.

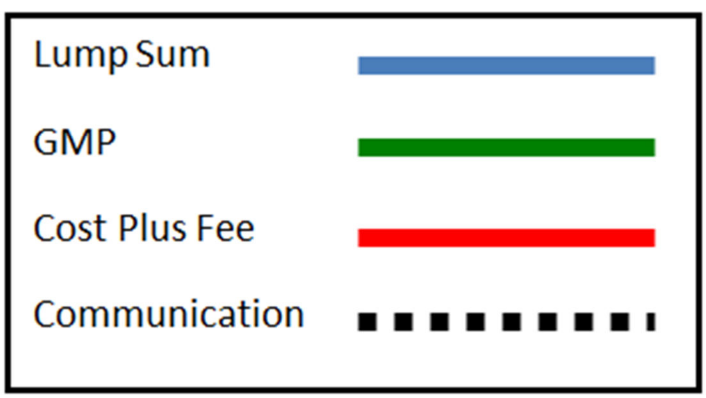
Project Delivery System

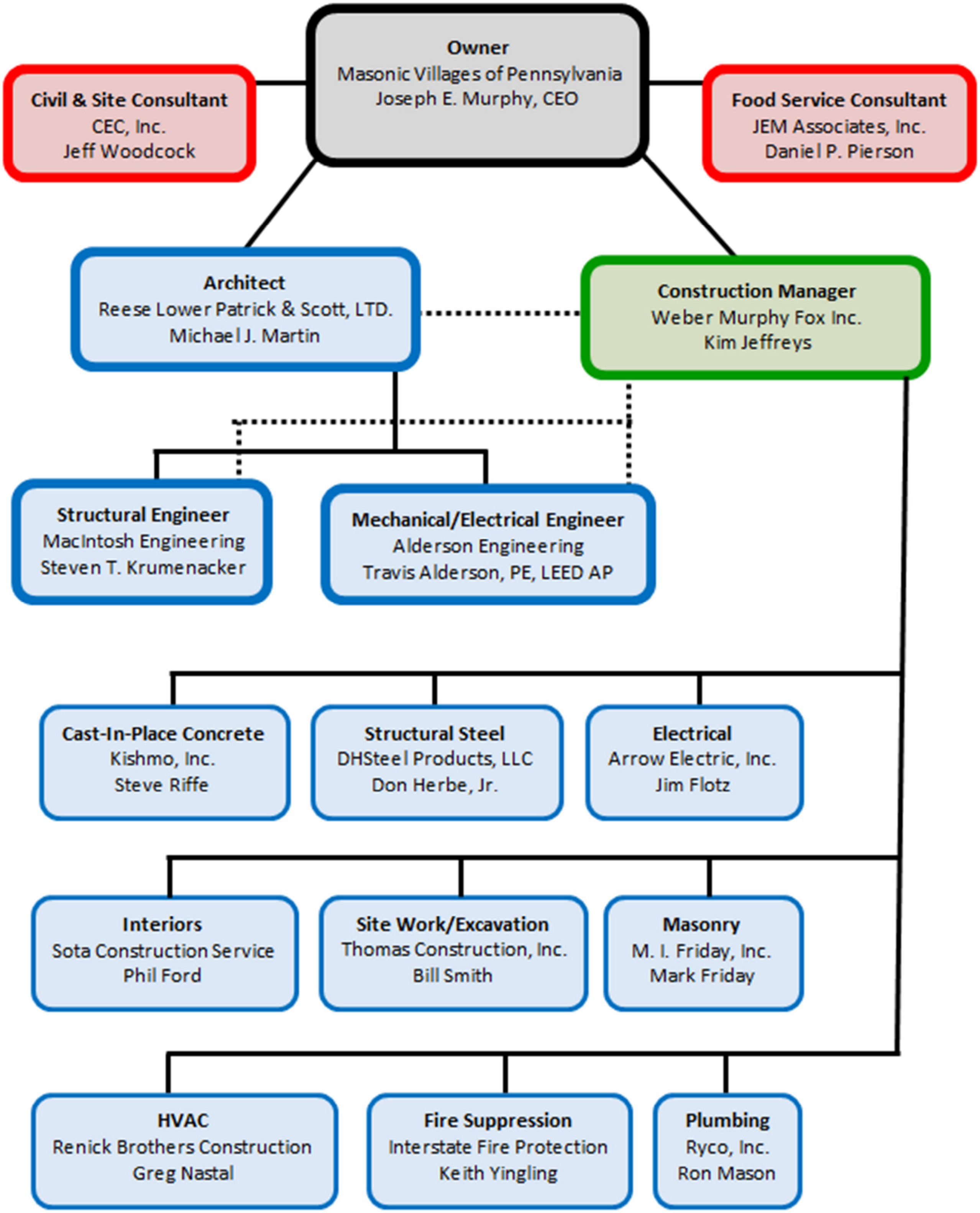
The project delivery system for the construction manager at risk on the additions and renovations of Masonic Village at Sewickley was negotiated through the use of a GMP contract. During the preconstruction phase, Masonic Village added Weber Murphy Fox to a small collection of prospective contractors. Carefully meeting with representatives from each firm, Masonic Village held private interviews to conduct the official selection process. Based on competency, projected fees, quality of previous work, and various other factors, Weber Murphy Fox was selected by the owner as the best CM for the project.

Shortly after being awarded the project, Weber Murphy Fox began to compile a list of qualified subcontractors for the various trades needed for the project. Contractors were then assembled by invitation only and trades were competitively bid. Following the bid, each job was narrowed down to three potential companies. These contractors were not always necessarily the lowest bidders but were who Weber Murphy Fox determined to be the most qualified. A detailed outline of the project delivery system and contract types is illustrated in Figure 2.

No bonds have been required for Masonic Village at Sewickley. The insurance used for the project is Builder's Risk Insurance. It is currently carried by Weber Murphy Fox and covers any mishaps that may occur during the course of construction.

Contract Types:

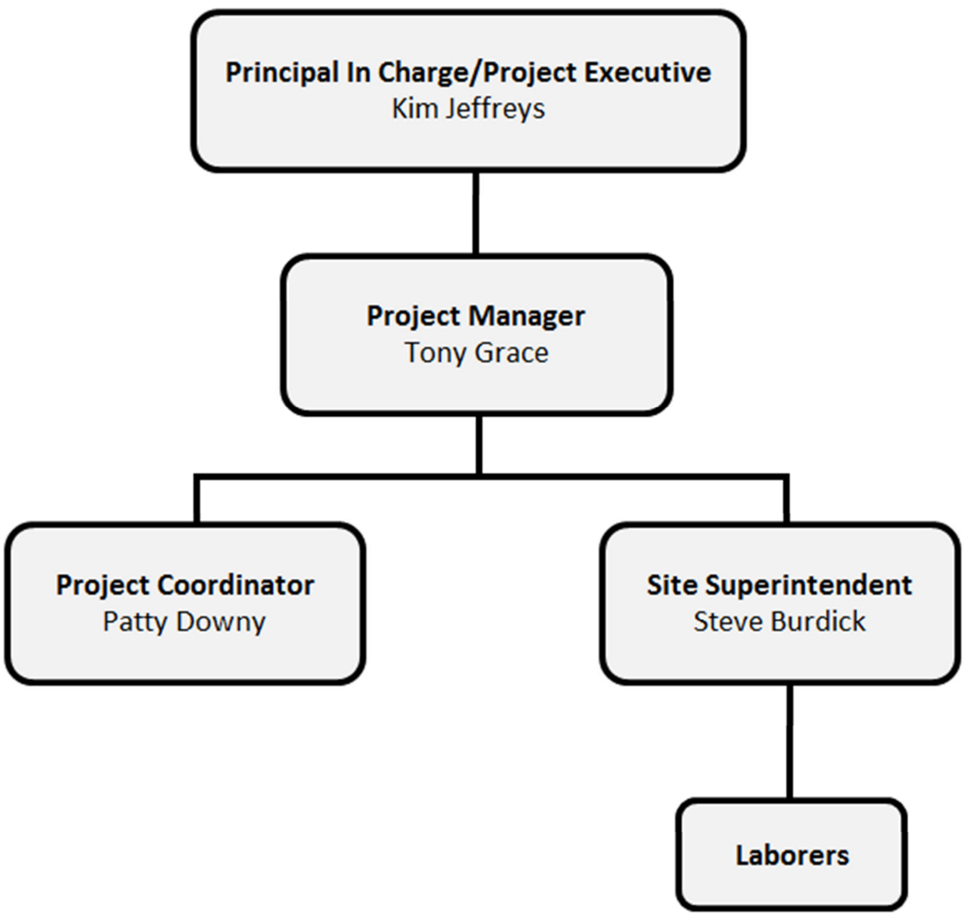




(**Figure 2:** Project Delivery Systems)

Staffing Plan

Given the relatively small size of the project, the staffing plan is fairly straightforward. The Principal In Charge/Projected executive, Kim Jeffreys, primarily oversees the job from Weber Murphy Fox's office headquarters in Erie, PA. Reporting directly to Mr. Jeffreys is Project Manager Tony Grace. Mr. Grace is stationed at one of the company's satellite offices in State College, PA. Although much of his work on the project is office-based, he does make weekly trips to the site and makes sure everything is running smoothly. Residing directly below the Project Manager are two main positions, Project Coordinator and Site Superintendent. The Project Coordinator, Patty Downey, has responsibilities similar to an Assistant Project Manager. She aids Mr. Grace by tracking things like submittals, RFI's, etc. Out in the actual field is Steve Burdick, Site Superintendent. Mr. Burdick is on site every day and supervises each subcontractor's daily activity. Figure 3 depicts a graphic representation of the project's staffing plan.



(**Figure 3:** Staffing Plan)

Building Systems Summary

(**Table 1:** Building Systems Checklist)

Yes	No	Work Scope
X		**Demolition Required**
	X	**Structural Steel Frame**
X		**Cast-in-Place Concrete**
X		**Precast Concrete**
X		**Mechanical System**
X		**Electrical System**
X		**Masonry**
	X	**Curtain Wall/Glazing**
	X	**Support of Excavation**

Demolition:

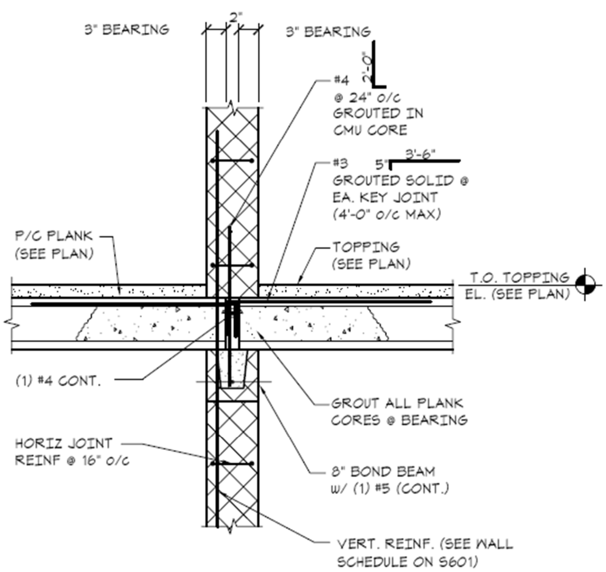
Demolition work occurring on the project is not scheduled to take place until Phase 3, when interior renovation work begins on the existing building. Since the purpose of the project is to add resident rooms to the newly constructed additions, most existing resident rooms will inevitably be demolished and relocated, leaving the previous space to be utilized in a different fashion. Much of the building's waste will come from demolition of interior walls. These assemblies are predominantly composed of metal stud framing, with small sections of masonry in some of the building's main internal bearing walls. Other waste includes floor tile, gypsum wall board (GWB), carpet, acoustical ceiling tile, etc.

Cast-in-Place Concrete:

The amount of concrete used on the project is relatively low compared to the size of the building. The entire first floor contains a 4" slab on grade. Since the building itself is positioned on a hillside, portions of the second floor will also contain a 4" slab on grade. Any elevated floor space within the second floor, as well as the entire third floor, needs a 2" topping slab atop precast concrete planks. This can be viewed below in Figure 4 and Figure 5. The only vertical concrete placement occurs where the small first floor region of Building A is located below grade. This is done through the use of metal wall forms. All concrete placement for the project is executed through the use of a concrete pump truck.

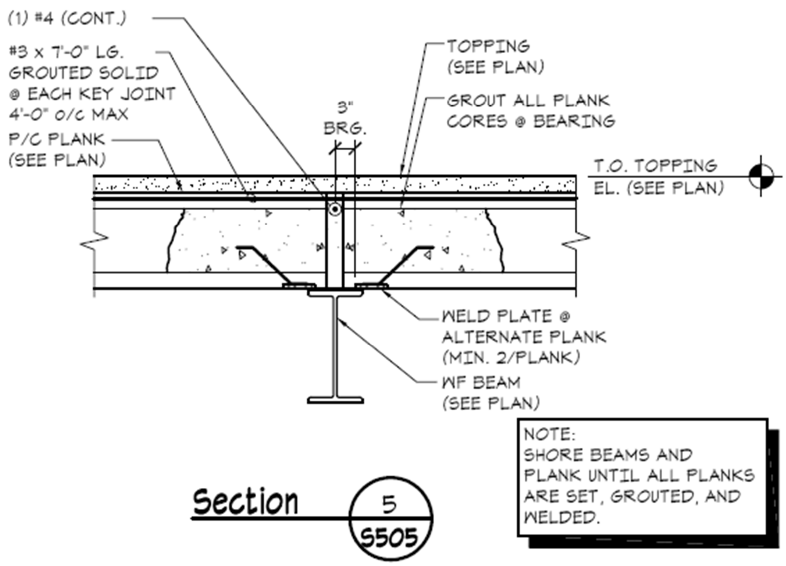
Precast Concrete:

Precast concrete is very abundant on the site. Planks are produced at a fabrication plant off site and trucked in for erection. Designers have implemented both hollow core and solid core concrete planks within the building's structural framework. A 50 ton truck crane is used to make all the necessary lifts on the project. Individual units span across the addition to each load bearing CMU wall. 2' long #4 anchor bolts are grouted into the CMU core at 24" on center to properly secure the units. Once in position, anchor bolts are then grouted to the precast planks as well. In some locations, steel wide flange beams are used for structural support of the planks over wide openings. These connections are made through the use of two weld plates that were installed in the planks during fabrication. Connection details are illustrated in Figure 4 and Figure 5.



(**Figure 4:** Precast to CMU Connection Detail)

- Courtesy RLPS, LTD.



(**Figure 5:** Precast to Wide Flange Connection Detail)

- Courtesy RLPS, LTD.

(**Figure 6:** Precast Plank Lifts)

- Courtesy WMF, Inc.

Mechanical System:

On the northwest corner of the site, an Evapco cooling tower is placed on a concrete pad. It is a closed circuit cooler and has a maximum capacity of 90,900 CFM. Intended to supply both the additions and the existing building, dimensions of the tower are roughly 12’ wide x 12’ deep x 21’ high. Once fluid leaves the tower it is transported underground into the mechanical room, which is located on the first floor. The mechanical room also contains 3 natural gas Fulton boilers, each of which are about 3,500 lbs. One of the boilers is dedicated to domestic hot water. It is rated at 84% efficient and has an output of 1,680 MBH. The other two boilers are WSHP (water source heat pumps). These boilers achieve an efficiency of 98% and each have an output of 1,960 MBH. Two 675 lb. Bell & Gossett water condenser pumps are responsible for dispersing fluid from the mechanical room at a rate of 826 GPM. In the attics of the two additions, two 2,500 CFM heat recovery units are used for the newly added zones.

The existing structure is also going to be tied into the mechanical system of the additions. Two rooftop units currently exist atop the flat roof of the present building. These units are to be demolished and replaced by new equipment. One apparatus is designated as a 2,500 CFM ventilation unit, whereas the other is going to be a 4,000 CFM WSHP. Also being added to the existing building are 4 make-up air units for the kitchen areas. Two units will be dedicated to each area and supply the zone with an additional 1,560 CFM. The fire suppression system of the addition is a wet pipe sprinkler system. The pipes contain pressurized water at all times and individual sprinkler heads will activate when they absorb excessive heat.

(**Figure 7:** Cooling Tower)

- Courtesy WMF, Inc.

Electrical System:

The electrical room is located on the first floor of the new addition directly next to the mechanical room. A 15kV feed is delivered underground from the utility and enters the electrical room on the west side. As the power enters the room it runs through a 480-208/120V Square D transformer rated at 75 kW. From here it is delivered to a 2000A QED main distribution switchboard connected to a main breaker that has been rated for the load. The MDP then sends power to numerous subpanels, including both 480/277V and 208/120V throughout the rest of the building. An 800kw 480/277V, 3 phase, 4 wire generator also exists next to the building's cooling tower. The generator's feed is also delivered underground to the west side of the electrical room. When it arrives in the room it enters a 2000A generator distribution panel that is responsible for providing power to its proper locations.

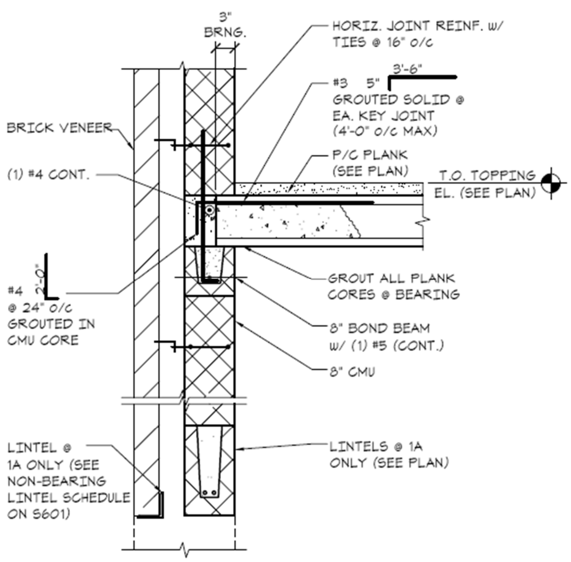
Masonry:

Masonry is the most abundant system within the building. Nearly all of the project's exterior walls, as well as many interior walls, are built with standard 8"x16" CMU blocks. These blocks are used for load bearing walls and comply with ASTM C 90 standards, which rate them at an average compressive strength of 2,000 psi. Two main classifications of mortar are used for bonding. Masonry set bellowed grade or containing reinforcing is to be of Type S; whereas applications of interior load-bearing or non-load bearing partition walls is to be set with Type N mortar. Nearly all exterior wall surfaces are also finished with a brick veneer. Ties and anchors are made from hot-dipped galvanized carbon steel with a class B-2 corrosion protective coating. Wire ties extend a minimum of halfway through the veneer with at least 5/8 inch cover on the outside face. The outer ends of the wire are to be bent at 90 degrees and extend at least 2 inches parallel to the face of the veneer. Face brick for the project is a product of Hanson Brick. The material is graded SW (severe weather) and is classified as FBS, which is standard face brick size. Actual dimensions are 3-5/8" wide by 3-5/8" high by 7-5/8" long. Application of the veneer is intended for areas in which the brick is directly exposed to the exterior.

Free-standing scaffolding was used for all masonry construction on the project. Much more scaffolding needed to be set up than originally planned for. Rather than relocating portions of the scaffolding for cost efficiency, the project team decided to take a different route in order to help make up time on the schedule. Rather than completely finishing the CMU erection before starting the brick veneer, the two tasks were completed simultaneously. As each section of CMU wall became finished, the brick veneer would chase it around the building. Figure 8 shows an exterior wall photograph with both CMU and brick veneer. Although it requires a much less efficient use of the scaffolding, the added equipment helped recover lost time.

(**Figure 8:** Area B Masonry)

- Courtesy WMF, Inc.



(**Figure 9:** Brick Veneer & Exterior Wall Detail)

- Courtesy RLPS, LTD.

Project Cost Evaluation

The project cost evaluation gives insight on the actual cost of construction for both the new additions as well as the renovation activities. It breaks down each section of construction and provides an overview on how much each one costs on a square foot basis. This section further compares real numbers against projected values of actual square foot and assemblies estimates derived from RS Means 2011.

Construction Cost:

The actual building construction cost is calculated by subtracting several items from the total cost of construction. These items include:

General Conditions

- Site Work
- Contingency
- Fee
- Insurance

Given the amount of heavy renovations as well as new construction, cost information has been broken down into multiple components. The following figures took into account both the renovation work as well as the 66,455 square feet of new construction.

Total Cost of New Construction:	**$15,187,799**
Cost/SF of New Construction:	**$229/SF**
Total Cost of Renovation Work:	**$4,940,277**
Cost/SF of Renovation Work:	**$112/SF**
Total Building Construction Cost:	**$20,128,076**
Average Cost/SF:	**$182/SF**

Total Project Cost:

The total project cost includes all items listed by Weber Murphy Fox used to produce their final project estimate. The following values have once again been broken down into renovations and new construction based on the represented square footages of each.

Total Cost of New Construction: **$16,855,373**
Cost/SF of New Construction: **$254/SF**

Total Cost of Renovation Work: **$5,940,822**
Cost/SF of Renovation Work: **$135/SF**

Total Building Construction Cost: **$22,796,195**
Average Cost/SF: **$206/SF**

Building Systems Cost:

The first three systems listed in the table below provide a cost/SF relative to the new construction as well as the overall cost/SF, given that is where they are primarily devoted to.

(**Table 2:** Building System Cost Data)

System	Total Cost	New Construction Cost/SF	Average Overall Cost/SF
Concrete	$848,104	$12.76	$7.68
Masonry	$1,127,509	$16.97	$10.21
Openings	$1,075,317	$16.18	$9.74
Fire Protection	$280,055		$2.54
Plumbing	$1,503,061		$13.61
HVAC	$2,330,870		$21.10
Electrical	$1,807,395		$16.36

Square Foot Estimate:

- **Reference Appendix B for tabulated square foot data**

Total SF of New Construction:	66,455 SF = $183.55/SF
Total SF of 2nd and 3rd floor:	62,895 SF
Perimeter adjustment for 2nd and 3rd floor:	(Actual – Given) 1252 SF – 735 SF = 517 SF $3.20 x 5.17 = $16.54/SF
New Adjustment:	$183.55/SF + $16.54/SF = $200.09/SF
2nd and 3rd floor story height adjustment:	$0
Total 2nd and 3rd floor estimate:	$209.09/SF x 62,895 SF = $12,584,660.55
Total SF of 1st Floor (Basement):	3,560 SF
1st floor adjustment for Basement:	$30.45/SF
1st floor story height adjustment:	(Actual – Given) x $2.05/SF (12ft – 10ft) x $2.05/SF = $4.10/SF
New Adjustment:	183.55 + 30.45 + 4.10SF = $218.10/SF
Total 1st floor (Basement) estimate:	$218.10/SF X 3,560 SF = $776,436.00
Total Square Foot Estimate:	$12,584,660.55 + $776,436.00 = **$13,361,096.55**

<u>Common Additives</u>

Beds:	$2825/bed x 128 beds = $361,600
Elevator:	$62,900
Location Factor:	1.01
Cost/SF:	$209.52/SF
Adjusted Total Estimate:	**$13,923,452.52**

MEP Assemblies Estimate:

- **Reference Appendix B for tabulated assemblies cost data**

HVAC

Hydronic, Natural Gas Boiler:	\$12.50/SF x 66,455 SF = \$830,687.50
Chilled Water Cooling Tower:	\$11.55/SF x 66,455 SF = \$767,555.25
Total HVAC:	**\$1,598,242.75**

Electrical

3 Φ, 4 wire Electrical Service:	\$40,400 x 1.25 (277/480V) = \$50,500.00
Lighting:	\$10.21/SF x 66,455 SF = \$678,505.55
Receptacles:	\$2.78/SF x 66,455 SF = \$184,744.90
Generator System:	\$256/kW x 800 kW = \$204,800.00
Total Electrical:	**\$1,118,550.45**

Plumbing

Pipe Installation:	\$21.25/LF x 25,000 LF = \$531,250.00
3 Fixture Bathrooms:	\$5,600/Unit x 128 Units = \$716,800.00
Total Plumbing:	**\$1,248,050.00**

Fire Suppression

Wet Pipe Sprinkler System:	\$2.80/SF x 66,455 SF = \$186,074.00
Total Fire Suppression:	**\$186,074.00**

Cost Comparison:

When comparing the actual and estimated cost values, the total cost of the project cannot be considered. RS Means does not account for fees and contingencies as would the total project cost. Therefore, it is important to note that the actual cost of new construction on Masonic Village comes in at $15,187,799. Using data obtained from RS Means Square Foot Costs: 2011, the calculated square foot estimate came out to be $13,923,452.52. This is a difference of only 8.3%. Given that a square foot estimate is only accurate to ± 15%, it is well within an acceptable range of values. More specific data on the calculations above can be viewed in **Appendix B**. Nonetheless, the overall addition to the nursing facility has been calculated to cost $209.52, compared to the real cost of $229/SF.

Four different MEP systems were estimated using RS Means Assemblies Cost Data: 2011. To estimate the cost of the building's HVAC system an estimate was performed on chilled water cooling towers as well as hydronic, natural gas boilers. Upon adding the two totals together, the HVAC system came in at $1,598,242.75. This number was discovered to be somewhat higher than the actual amount of $1,446,060.80 and may be due to the fact that some of the HVAC equipment supplying the addition is already in place in the existing building. In order to analyze the electrical system, lighting, receptacles, services, and generator systems were analyzed. The total estimated value of electrical work was $1,118,550.45. When compared to the actual amount of $1,122,424.95, the estimate is practically dead-on being within 1%. The third assembly to be calculated was the plumbing system. Linear feet of piping as well as three fixture bathrooms were the two components considered in the estimate. The actual cost of the plumbing for the job is $1,299,859.80 and was found to be within 4% of the estimated value. Last to be calculated was the fire suppression system. Masonic Village contains a wet pipe sprinkler system covering all 66,455 SF of the building. This system was discovered to be within 8% of the actual value of $174,112.10. Overall, each assembly was fairly close to the actual documented values. Considering an assemblies estimate is accurate to ± 10%, each estimate was within the confines of its margin of error. **Appendix B** references all cost data used to perform the MEP assemblies estimate.

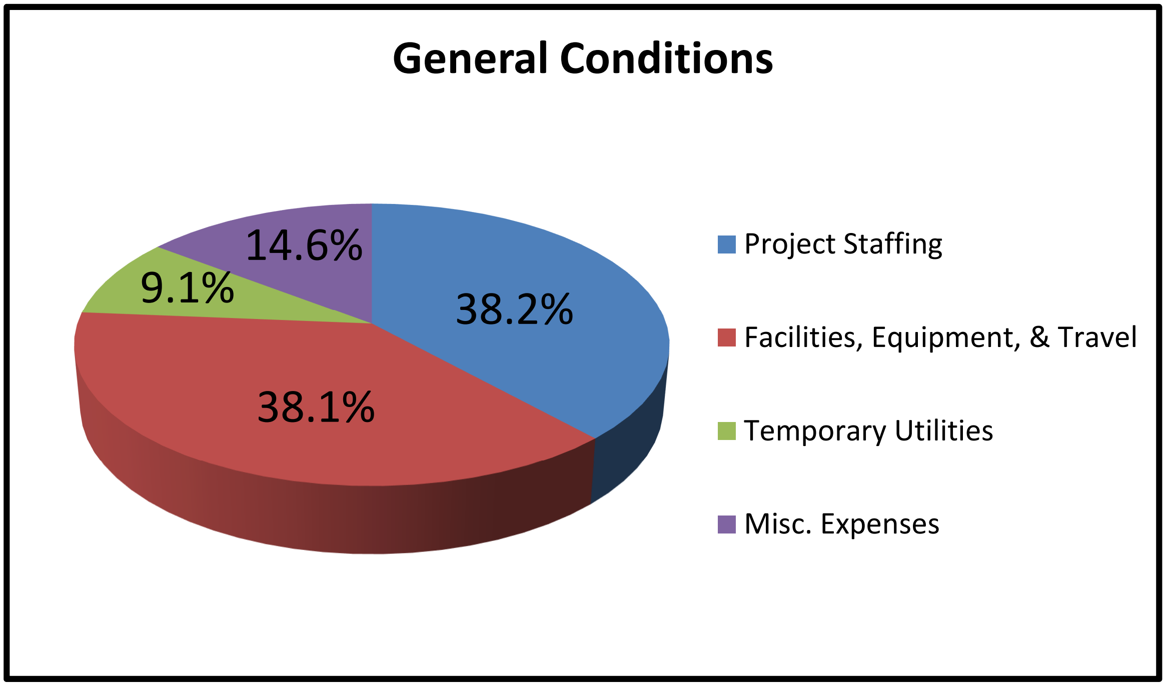
General Conditions Estimate

The general conditions estimate created for Masonic Village at Sewickley has been broken down into several different components. These categories include project staffing, facilities and equipment, temporary utilities, and miscellaneous expenses. Table 3 illustrates each of these costs on a week-by-week breakdown. To view a more detailed general conditions estimate refer to Table 16 of **Appendix C**.

(**Table 3:** Basic GC Breakdown)

	Weekly Rate	Unit	Quantity	Total Cost
Project Staffing	$2,788	Week	106	$295,488
Facilities, Equipment, & Travel	$1,068	Week	106	$113,256
Temporary Utilities	$664	Week	106	$70,400
Miscellaneous Expenses	$2,782	Week	106	$294,856
TOTAL:	**$7,302**	**Week**	**106**	**$774,000**

The estimate for project staffing is the total combination of three constituents. These items include the field engineer, project supervision, and miscellaneous labor. Considering there are only full-time two staff members and two that are dedicated to this particular project part-time, labor only accounted for slightly more than one-third of the total general conditions cost. Although labor makes up an uncharacteristically low percentage of the overall general conditions cost, it helped in providing a competitive total price for the owner. The second category in the breakdown is a compilation of five components. Facilities and equipment is made up of the field office, temporary toilet, storage trailers, travel, and equipment rental. Travel makes up the largest part of this category, being estimated at $72,096. This is because the field engineer makes a 200 mile round trip to the site each and every day, as well as the project manager's 300 mile weekly round trip. It becomes evident that this excessive charge offsets some of the savings created by a small project team. Temporary utilities are the third item in the analysis. Included in the estimate is temporary water, electric, and heat. Temporary heat is the largest part of this portion at $32,000, followed by temporary electric at $24,000, and trailed lastly by temporary water at $14,400. The remaining items in the detailed general conditions estimate not yet accounted for have been lumped into a single category titled miscellaneous expenses. A graphical representation showing the percent of general conditions each category makes up can be seen in Figure 10.



(**Figure 10:** GC Breakdown by Category)

The overall general conditions cost for the project has been estimated at $774,000 of the total GMP. Also included in **Appendix C** is a list of fees and contingency costs, located in Table 17. The project team was involved in a number of pre-construction activities. The fee for such work has been billed at $151,000. The total construction management fee for the actual construction process is listed at $453,000. Given the struggling economic conditions of current times, this fee has been reduced to only 2% of the total cost of construction. The final line item in Table 17 is construction contingency. The project team has been allotted $2,094,846 for contingency. Therefore, the total billable charges between fees and contingency provide a maximum total of amount of $2,698,846.

Detailed Assemblies Estimate

Since there are no typical bays, a detailed assemblies estimate was performed as opposed to a detailed structural system estimate. In order to create a detailed assemblies estimate for Masonic Village at Sewickley, the structural system was broken down into four major categories and further subdivided into 16 individual components. The larger categories include foundation, floor construction, bearing walls, and roofing system. The generated estimate includes labor, material, and equipment cost in the figures used for computation. Cost values were obtained from RS Means Assemblies Cost Data 2011 and paired with actual dimension of line items extracted from project drawings and specifications. **Appendix B** displays all tabulated values used in conducting the structural system estimate.

Foundation:

Four different foundation elements were included in this portion of the estimate. The building's foundation includes continuous strip footings, caissons, grade beams, and underpinning of the existing assisted living building. Since the building is positioned on a hillside the 2nd floor, as well as the 1st, each requires the use of strip footings. The smaller 1st floor region contains 555 LF of footings, whereas the 2nd floor calls out 828 LF. Both footings are made of the same concrete mix and are dimensioned at 2' wide by 1' thick. Caissons are second on the list of foundation elements. Between Building A and Building B there are a total of 40 caissons in the makeup of the foundation. Each caisson is 3' in diameter and approximately 11' deep. Atop the caissons rest a number of grade beams. Grade beams in the foundation differ vastly in size and span. The grade beams 2'6" wide by 4'0" deep are the most abundant on site, adding up to 386 LF. Not very far behind them are grade beams sized at 2' wide by 4' deep. Only trailing by five feet, there are a grand total of 381 LF. The third size used on site is much larger in girth, at 4' wide by 4' deep, and make up a length of 223 LF. Lastly are the heftiest grade beams of all, which account for only 60 LF of the building's substructure. These beams are 4' wide by 6' deep. The final element considered in foundation work is underpinning. Given that both the additions each connect to the existing building in two separate locations, engineers have dictated a need for underpinning the foundation of the original building. An estimated 86 CY of concrete will be needed for this procedure. The following values taken from RS Means Assemblies Cost Data 2011 and used to estimate the cost of foundation work at **$485,761.85:**

Strip Footing	-	$36.95/LF
Caissons	-	$1,735/EA
Grade Beam (2’6”x4’)	-	$325/LF
Grade Beam (2’x4’)	-	$243/LF
Grade Beam (4’x4’)	-	$412/LF
Grade Beam (4’x6’)	-	$421/LF
Underpinning	-	$350/CY

Floor Construction:

Floor construction is comprised of two primary components. These constituents are slabs on grade and precast concrete planks. Two different size slab thickness were used in conjunction with the project. The sub-grade 1st floor of Building A calls for a 6” reinforced slab. This slab covers the entire 3,835 SF 1st floor region. The second slab on grade used for the project is a 4” reinforced slab. This size slab is used for the entirety of the 2nd floor. The amount of 2nd story floor space requiring a slab on grade is roughly 28,529 SF. The remaining square feet will require elevated floor space. All elevated floors are made of 10” thick precast concrete planks, which span across the bays of the structure. Between the 2nd and 3rd floor, 35,301 SF of floor space require the use of this type of system. All estimated values of precast include the desired 2” concrete topping slab called for in the design specifications. The numbers below were used to generate an estimate of **$640,294.62** for the total floor construction:

6” Slab on Grade	-	$5.98/SF
4” Slab on Grade	-	$4.96/SF
Precast Concrete Planks	-	$13.48/SF

Bearing Walls:

Two types of wall assemblies were implemented in Masonic Village at Sewickley. The first system, which was used on a very small scale, was cast-in-place (CIP) concrete. All concrete was placed using a concrete pump truck. Both the means of placement and formwork were considered in the values used to conduct the estimate. The only region of the building that actually uses CIP concrete walls is the first floor. The 3,835 SF area only has 379 LF of concrete bearing walls. Therefore, the predominant means of structural support is CMU load bearing walls. Two different sizes of block were implemented in the structure. The first size, which is 8”x16”x16”, is used below grade. Blocking of this size accounts for 15,990 SF. The second size CMU used on the project is dimensioned at 8”x8”x16”. This is typically the standard size CMU most often used in construction. The amount needed to construct all exterior bearing walls is 45,521 SF, whereas the quantity demanded for interior bearing walls comes in at 40,227 SF. The total estimate for bearing walls in the building was found to be **$1,268,289.53**, which is certainly the most dominant number in the structural system estimate. The succeeding values were used for calculations:

Cast in Place Walls	-	$261/LF
16” CMU	-	$14.25/SF
8” CMU	-	$10.98/SF

Roofing System:

Lastly, the roofing system was analyzed to complete the structural system estimate. The building’s roof is comprised of prefabricated wood trusses, covered with 5/8” sheathing. The trusses were estimated on a square foot basis. The total amount of roof space to be enclosed is 45,635 SF. RS Means Assemblies Cost Data 2011 provided a value of $2.50/SF of roof space, which includes both material and labor. To account for the 5/8” sheathing, another $2.50/SF was added to the estimate. This provided a final roof system value of $5/SF. Upon multiplying this amount by the overall square footage, the roofing system has been estimated to be **$228,175.**

The following tables provide an overview of the detailed structural system estimate for the project. Table 4 illustrates how much of the estimate each major system accounts for, whereas Table 5 provides an itemized breakdown of individual structural components within the systems. The total detailed structural estimate has been computed at **$2,622,521**. When compared to the real value of $2,552,600 used by the construction team, there is a difference of only 2.7%. Given that a detailed estimate is accurate to ± 5%, the calculated value is within a reasonable margin of error.

(**Table 4:** Structural System Costs)

Item	Percentage	Overall Cost
Foundation	18.5%	$485,761.85
Floor Construction	24.4%	$640,294.62
Bearing Walls	48.4%	$1,268,289.53
Roofing System	8.7%	$228,175.00
TOTAL:	**100%**	**$2,622,521.00**

(**Table 5:** Structural System Breakdown)

Item	Unit	Cost/Unit	Cost
1st Floor Strip Footing	555 LF	$36.95/LF	$20,507.25
2nd Floor Strip Footing	828 LF	$36.95/LF	$30,594.60
Caissons (3' x 11')	40 EA	$1,735/EA	$69,400.00
Grade Beam (Size 1)	386 LF	$325/LF	$125,450.00
Grade Beam (Size 2)	381 LF	$243/LF	$92,583.00
Grade Beam (Size 3)	223 LF	$412/LF	$91,867.00
Grade Beam (Size 4)	60 LF	$421/LF	$25,260.00
Underpinning	86 CY	$350/CY	$30,100.00
6" Slab on Grade	3,835 SF	$5.98/SF	$22,933.30
4" Slab on Grade	28,529 SF	$4.96/SF	$141,503.84
Precast Planks w/2" Topping	35,301 SF	$13.48/SF	$475,857.48
Cast-in-Place Walls	379 LF	$261/LF	$98,919.00
16" Exterior CMU Walls	15,990 SF	$14.25/SF	$227,857.50
8" Exterior CMU Walls	45,521 SF	$10.98/SF	$499,820.58
8" Interior CMU Walls	40,227 SF	$10.98/SF	$441,692.45
Trusses & Sheathing	45,635 SF	$5.00/SF	$228,175.00
TOTAL:			**$2,622,521.00**

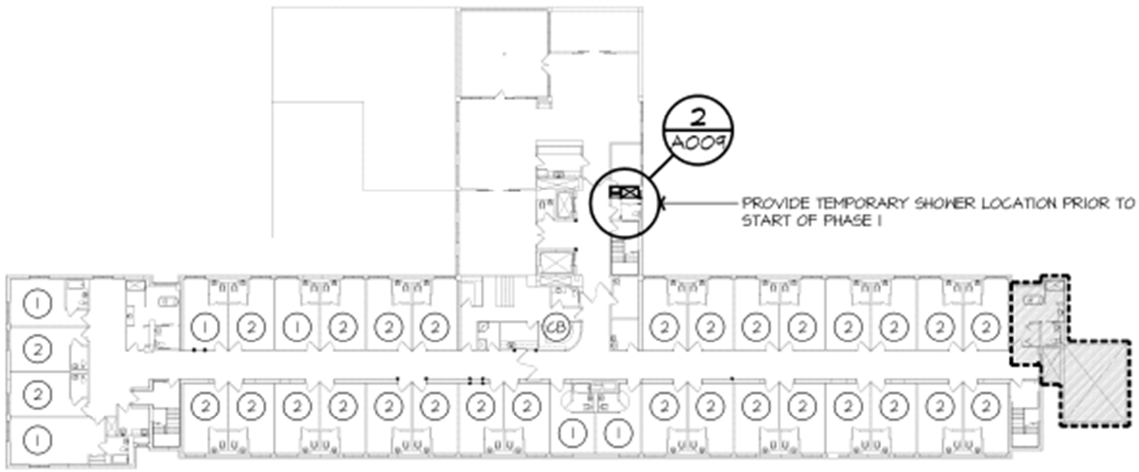
Site Layout Planning

Phasing on the Masonic Village project is a very intricate process. The job consists of five phases and has several major milestones that need to be well-tracked, including health board inspections and owner move-in dates of various areas. Phase 1, seen in Figure 11, is merely preliminary site work, foundations, and the relocation of existing parking lots. The property is fairly sizable, making equipment and material storage of lesser concern. Benching is used to excavate the 3,000 SF first floor. Although most of the second floor is at grade level, the excavated soil is used to backfill an ivany wall on the east side of the site. A more detailed layout of phase 1 can be viewed in **Appendix A**.

Phase two, detailed in Figure 12, is where most of the major new construction occurs. It involves the majority of the development of both the east and west wings. It is important for the additions to remain on schedule, considering dates have already been set to relocate residents from their current rooms. CMU load bearing walls provide structural support for the building. A 50 ton truck crane then follows behind by moving east and west along the site's access road, as seen in **Appendix A**, and sets the precast concrete planks for the floors above. Once the floors are set, scaffolding is shuffled around and the CMU walls continue upward.

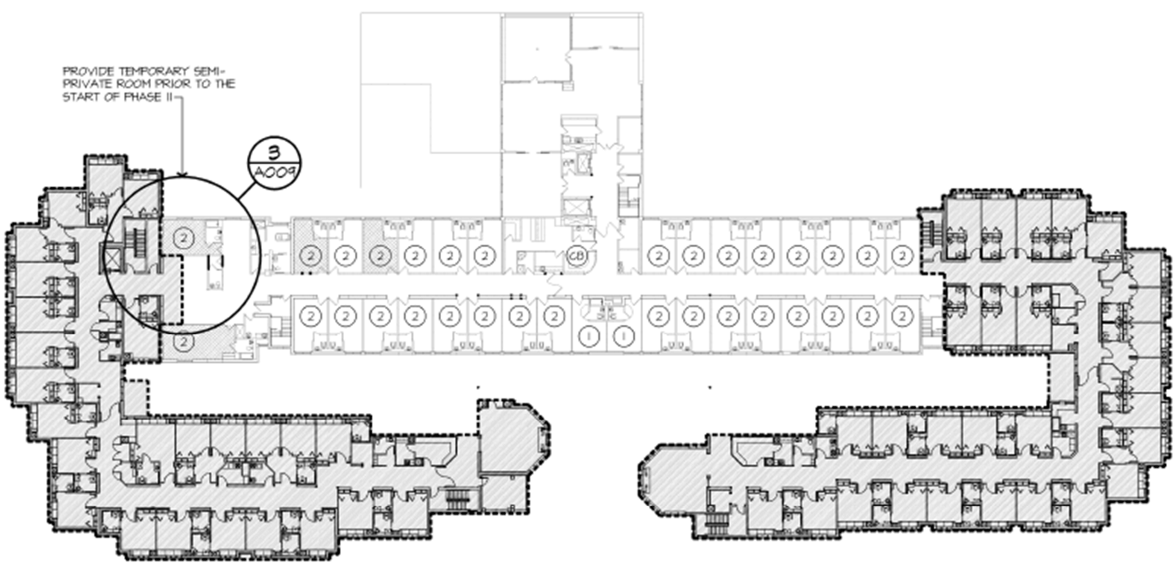
After both wings have been capped off, phase three reconnects the additions to the existing building at a second point along the existing south wall. Upon being reconnected to the original structure, heavy renovation work takes place within the existing building. Patient rooms are demolished and relocated away from the building's core. A graphic of Phase 3 can be seen in Figure 13 and a more detailed layout of the region is also displayed in **Appendix A**.

Upon completion of all new construction, work proceeds forward with the 40,000 SF of renovation work that makes up phases four and five of the project, seen in Figure 14 and Figure 15. Phase four focuses on renovating spaces near the two points at which the new additions were first connected to the previously existing structure and phase five involves wrapping up the remodel of public gathering spaces at the front of the nursing building. These areas consist of nurse stations and other specialized healthcare rooms.



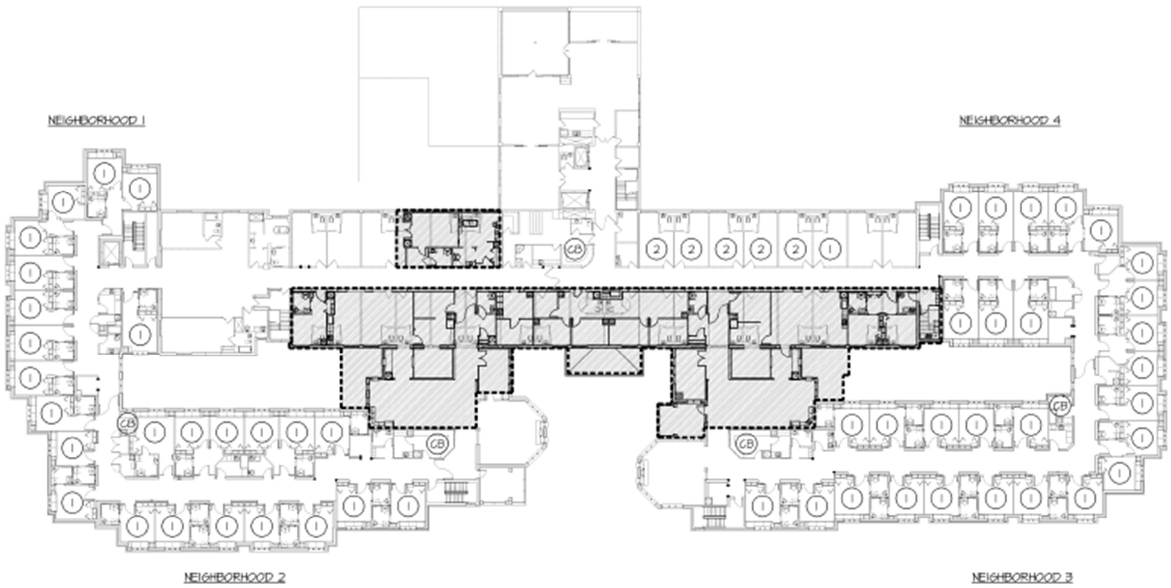
(**Figure 11:** Phase 1 [Site Development])

- Courtesy of Reese, Lower, Patrick, and Scott Architects



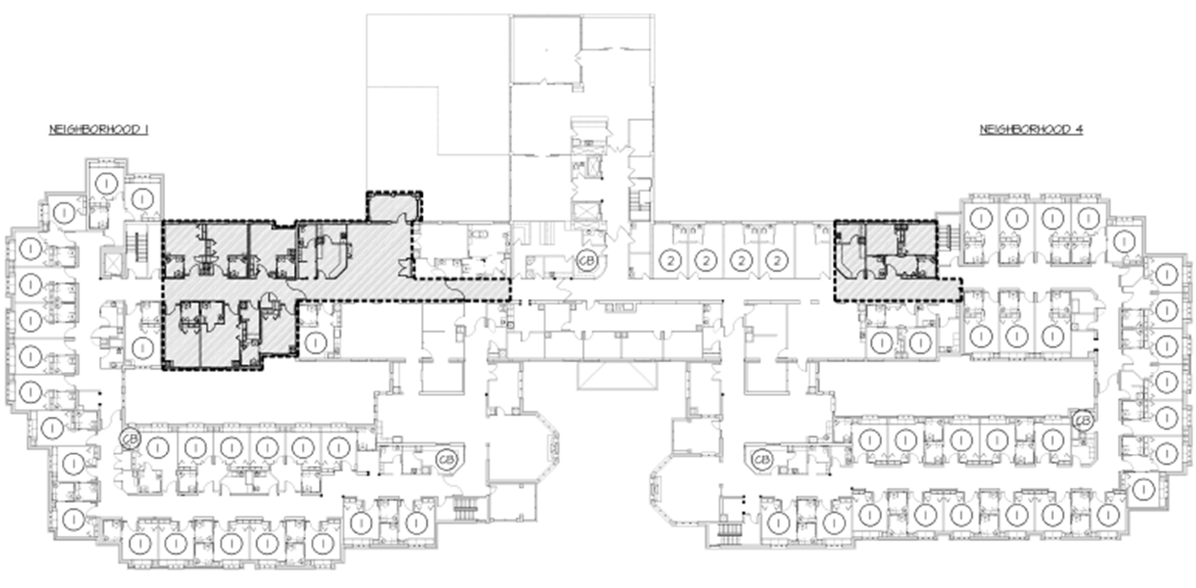
(**Figure 12:** Phase 2 [Constructing Additions])

- Courtesy of Reese, Lower, Patrick, and Scott Architects



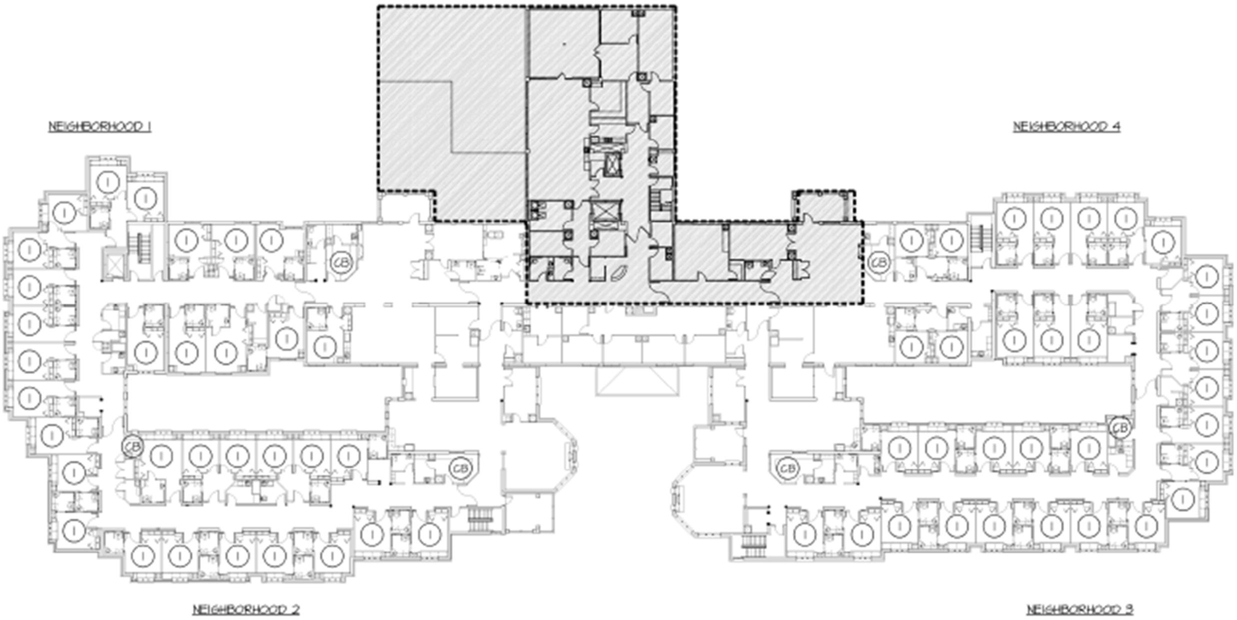
(**Figure 13:** Phase 3 [Connecting the Additions])

- Courtesy of Reese, Lower, Patrick, and Scott Architects



(**Figure 14:** Phase 4 [Heavy Renovations])

- Courtesy of Reese, Lower, Patrick, and Scott Architects



(**Figure 15:** Phase 5 [Light Renovations])

- Courtesy of Reese, Lower, Patrick, and Scott Architects

Project Schedule Summary

- Please reference **Appendix D** for a full project schedule summary, which notes entities such as preconstruction processes, milestone activities, and owner turnover dates.

Foundation:

Several different activities compromise the foundation work of the project. Following any preliminary site work, caissons are drilled and poured for each of the two additions. This process is then pursued sequentially by pouring caisson caps, grade beams, and various column footings. Concrete is first placed for Building B and later followed by Building A. Foundation walls are then put into place, given adequate cure time of the concrete. For the most part, walls are primarily made up of CMUs. However, Building A does contain several poured concrete walls in locations surrounding the first floor, which is partially below grade. Nonetheless the building's primary load carrying foundation elements are ultimately caissons and grade beams.

Structure:

A concrete slab on grade is the first part of the structure to be put in place. The slab is poured only in Building A, where the first floor is partially below grade. Precast concrete planks are positioned on top of both the poured concrete and CMU foundation walls. Once into place, CMU exterior walls are built up to what is technically designated as the 'third' floor, where another layer of precast concrete planks are set. The erection process is then followed by adding the third floor's CMU walls; at which point the roof framing process can begin. Wooden roof trusses and sheathing are subsequently placed atop the CMU exterior walls, which finally completes the buildings structural skeleton.

Enclosure:

Whereas asphalt shingles are applied to the new gabled rooftops, fully adhered EPDM roofing replaces the existing flat roof of the original structure. While roof coverings are being added, brick veneer works its way up the building simultaneously. Small regions of vinyl siding are also added to certain areas following a solid head start of the brick casing. As each trade begins to wrap up, the enclosure is finally complete with the installation of windows and exterior doors.

Finishes:

Finishes are one of the biggest portions of the project schedule. Even after the two additions are completed and turned over to the owner, the project will just be entering phase three of five. The remaining phases are dedicated to renovating the previously existing building, which is almost entirely nothing but finish work. Work includes things like drywall, painting, flooring, trim, etc. Finish work for phases two through five is expected to last approximately one year.

Detailed Project Schedule

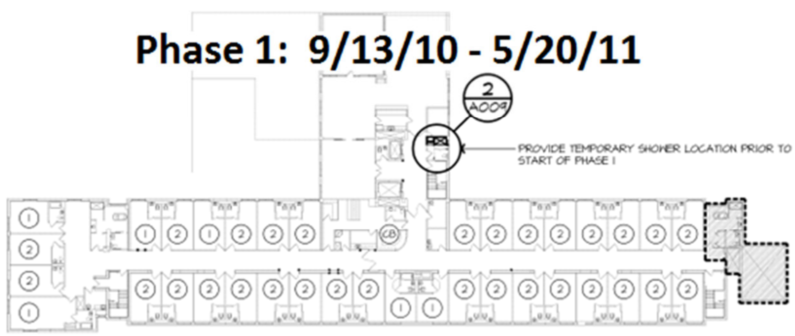
A detailed project schedule for Masonic Village at Sewickley has been assembled to further break down the five major phases of construction. A more detailed breakdown of activities creates an opportunity for a better analysis of project planning and correlation of activities. A full detailed project schedule can be viewed in **Appendix D**, which further illustrates the lifecycle of the project on a step-by-step basis.

Upon completion of the design process, a GMP was signed by Weber Murphy Fox in which they were officially able to begin construction activity. Due to the sequencing of the project, external factors such as weather have a more significant impact at the beginning of the schedule than it does towards the end. This is due to the fact that phases 1-3 are new construction and phases 4-5 are interior renovations. Therefore, the ability to keep on track during the early stages of development has the ability to either make or break the construction manger's anticipated final completion date. Expected dates of construction activity have thus far been scheduled from September 13, 2010 – September 27, 2012. This time frame reflects both the 66,455 SF of new construction, as well as the 40,000 SF of interior renovations to the existing nursing facility. Dates of several processes critical to the construction schedule are provided in below in Table 6.

(**Table 6:** Building Process Dates)

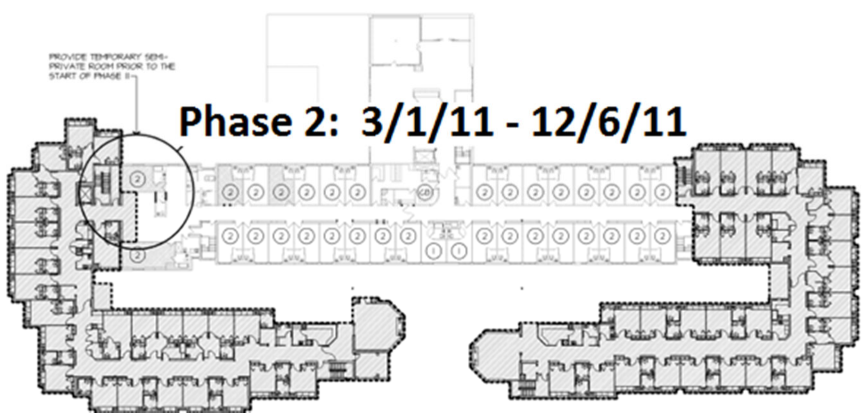
Site Development:	9/14/10 – 12/23/10
Foundations:	1/3/11 – 1/28/11
Concrete Placement:	1/24/11 – 2/24/12
Precast Planks:	3/15/11 – 3/21/12
Masonry:	3/18/11 – 3/30/12
MEP:	4/18/11 – 9/12/12
Roofing:	6/10/11 – 4/17/12
Building Enclosure:	6/28/11 – 5/2/12
Finishes:	8/8/11 – 9/13/12
Openings:	9/5/11 – 8/2/12
Final Site Work:	5/7/12 – 8/31/12
Turnover/Commissioning:	8/31/12 – 9/27/12

Project phasing of the facility is also a unique aspect of the construction schedule. The owner intends to chase the construction team around the building and occupy the spaces as each phase becomes complete. Therefore it is essential for project development to remain on or ahead of schedule, so as to avoid creating delays in anticipated move-in dates. Following the completion of phase three, all residents are planned to be relocated to the newly constructed additions. The shift will allow renovation work to begin on the previously existing resident rooms. A breakdown of project phasing paired with expected dates of construction is displayed in Figures 16-20.



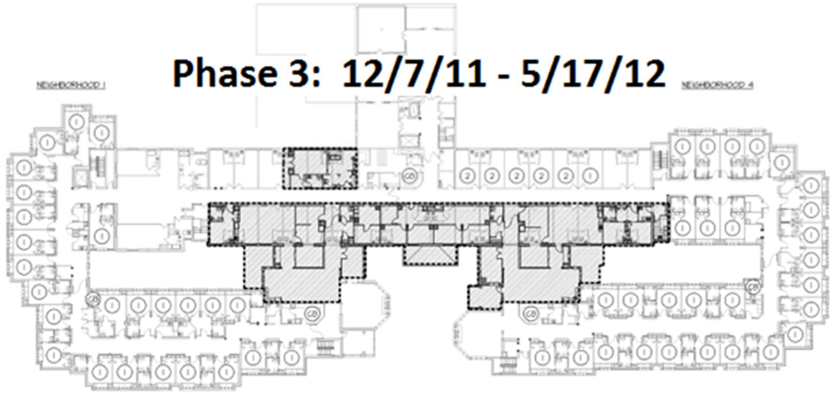
(**Figure 16:** Phase 1 Construction Dates)

- Courtesy of Reese, Lower, Patrick, & Scott Architects, LTD



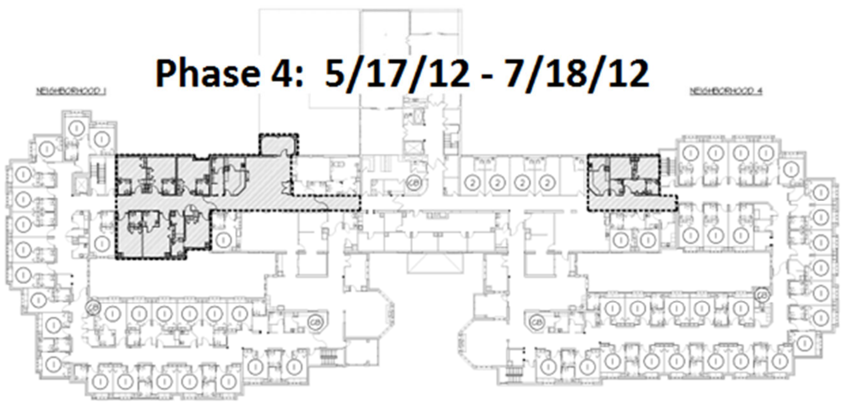
(**Figure 17:** Phase 2 Construction Dates)

- Courtesy of Reese, Lower, Patrick, & Scott Architects, LTD



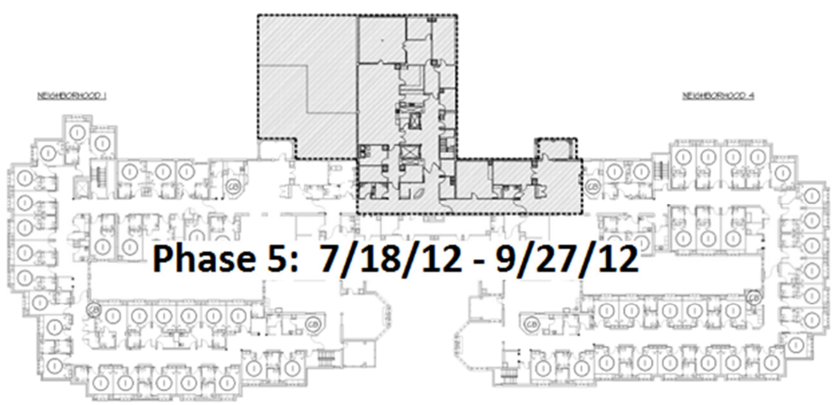
(**Figure 18:** Phase 3 Construction Dates)

- Courtesy of Reese, Lower, Patrick, & Scott Architects, LTD



(**Figure 19:** Phase 4 Construction Dates)

- Courtesy of Reese, Lower, Patrick, & Scott Architects, LTD



(**Figure 20:** Phase 5 Construction Dates)

- Courtesy of Reese, Lower, Patrick, & Scott Architects, LTD

LEED Evaluation

Masonic Village at Sewickley is not currently pursing any sort of LEED accredited rating. Nonetheless, a complete scorecard of LEED 2009 for Healthcare: New Construction and Major Renovations has been assembled to assess all LEED points the project currently qualifies for. This scorecard can also be used to direct specific attention to points that may be attainable with minimal additional effort by the project team. A completed LEED for Healthcare scorecard can be viewed in **Appendix E**. The intent of the evaluation is to further help bring to light the possibility of actually achieving a LEED rating on the project.

Sustainable Sites is the first major category included on the scorecard. This section accounts for 18 of 110 possible points. The most important thing to note about this category is that the project meets both prerequisites necessary to actually earn the points within the sustainable sites section. Prerequisites include construction activity pollution prevention and environmental site assessment, both of which focus on airborne dust generation, soil erosion control, and environmental contamination. The building's strongest areas in the sustainable sites category are alternative transportation, stormwater design, and having a connection to the natural world. Site conditions allow for public transportation access as well as bicycle storage and changing rooms. The size of the parking lot meets local zoning requirements but is not excessive, this encourages carpooling and alternative means of transportation. Stormwater drainage is also a critical issue in this section. An extensive stormwater system provides ample quality control for reducing environmental disruptions to natural hydrology and managing stormwater runoff. The last strong point in this section is connection to the natural world. Two large courtyards constructed in each of the building's wings provide an outdoor place of respite, allowing patients and staff to benefit from direct access to a natural environment. Judging by the existing conditions the project was awarded 5 points for alternative transportation, 2 points for stormwater drainage, 2 points for connection to the natural world, and 2 points for other. This adds up to 11 out 18 points for the sustainable sites category.

Water efficiency ranks as a 9 point category. Once again the building meets both prerequisites. It experiences a 20% reduction in water usage and minimizes potable water use for cooling equipment. The project scored very well in this section and achieved a minimum of 1 point for each topic. After a detailed investigation, Masonic Village at Sewickley earned 7 out of 9 points on this part of the scorecard. Low flow toilets are the primary contributor to the facility's reduced water consumption. Achieving the reduction provided 5 LEED points in the water efficiency portion. The remaining 2 points were earned by eliminating the use of potable water in both mechanical systems and landscape irrigation.

Energy and atmosphere is the largest point category on the scorecard. Although it supports only seven topics, this section accounts for 39 possible LEED points. Energy and atmosphere has three prerequisites, which the project surprisingly fulfills once again. Each prerequisite's primary focus is on the building's energy efficiency. The single most important topic in this section, and more importantly the entire scorecard, is to optimize energy performance. This single line item can range anywhere from 1 to 24 LEED points. Table 7 illustrates the required efficiency for a given amount of points. Top of the line mechanical units with advanced control systems have been implemented on the project. High efficiency boilers, cooling tower, and advanced lighting control systems are the primary focus resulting in the building's exceptional reduction in energy. Upon meeting with the project manager, the building is an anticipated to have a 36% reduction in energy consumption when compared to similar facilities throughout the United States. This allowed for 18 LEED points to be awarded for the optimizing energy item. 2 additional points were allotted for the advanced control systems that are being installed to compliment the project's efficient MEP systems. A total of 20 LEED points were awarded to the project under the energy and atmosphere section of the scorecard.

(**Table 7:** Points for Optimizing Energy Performance)

New Buildings	Existing Building Renovations	Points
12%	8%	1
14%	10%	2
16%	12%	3
18%	14%	5
20%	16%	7
22%	18%	9
24%	20%	11
26%	22%	13
28%	24%	14
30%	26%	15
32%	28%	16
34%	30%	17
36%	32%	18
38%	34%	19
40%	36%	20
42%	38%	21
44%	40%	22
46%	42%	23
48%	44%	24

- Courtesy of usgbc.org

The next topic on the scorecard is materials and resources. This category contains two prerequisites. It is believed that the project satisfies both these requirements, however only one is known for certain. Provided all prerequisites are accounted for, Masonic Village at Sewickley earned 6 out of 16 points on this portion of the scorecard. These points were earned through things like utilizing local resources, implementing non-mercury based lamps, and supplying an adequate amount of freestanding furniture.

The final category in which the project meets the necessary prerequisites is indoor environmental quality. A total of 18 points can be obtained in this section. Outdoor air monitoring and indoor chemical and pollutant source control play a huge part in earning points for the facility. Also contributing to indoor environmental quality is the controllability of lighting and thermal comfort systems. Nonetheless, it is still important to have a reconnection with the outdoor natural environment. The implementation of numerous large windows plays a huge role in further developing this scenario. Large windows provide a lot of natural light to indoor space, which has ultimately been proven to have a positive effect on an individual's personal mentality. In public gathering spaces, large windows provide just a small barrier between inside and outside. Overall, the project was given 10 out of 18 points for indoor environmental quality.

The last two categories are innovation in design and regional priorities. Not only did the project not meet either section's prerequisites, it did not even qualify for a single topic within the categories. Since there was no integrated project delivery, the building is somewhat lacking in innovative designs to the structure. The regional priority section deals with reaching out to the community and further educating the public on the benefits of LEED. Not much attention was given to this section either. Between the two categories 0 out of 10 points were awarded.

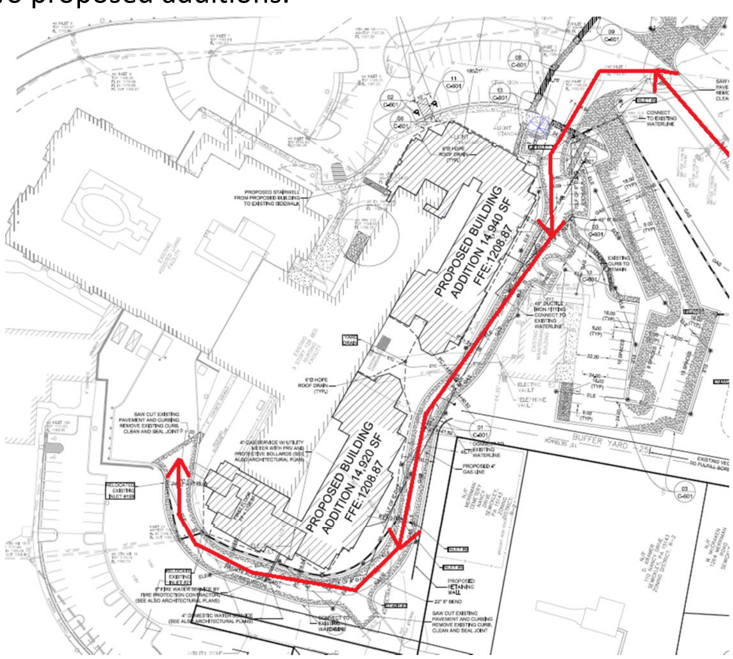
Overall, Masonic Village at Sewickley scored surprisingly better than might have been expected for a facility being one to not purse a rating. The project as a whole earned 55 out of 110 points. By definition, this is a LEED Silver rating. Upon meeting with the project manager to further review the scorecard, it was discovered that the project team was unaware of how many LEED points they actually qualify for. Research from Technical Report 2 is currently being used to inform the project team of the building's current qualifications and discuss the opportunity of actually earning a LEED rating on the project.

Constructability Challenges

Site Logistics:

One major challenge on the project is the configuration of the building itself. The structure contains two separate wings, each of which are located in an extremely constricted region of the owner's property. It is often problematic for various trades to function concurrently while trying to maintain materials and equipment within the confines of the site boundary. Congestion frequently leaves a cluttered site, in which subcontractors need to make a conscientious effort to try and avoid slowing each other down. Proper sequencing and positioning of trades by the project team is of absolute importance to the timely development of the facility.

To further complicate the logistics issue, there is only one available access road throughout the entire lifecycle of the project. The access road runs along the south wall and loops around to the west before it terminates as a dead end road. Therefore, every piece of machinery that drives down the path has to turn around and exit from the same gate in which it entered. If other large pieces of equipment happen to be functioning simultaneously and are blocking the road, each operator has to retreat sequentially such that the innermost machine has a clear path to exit before the others can reenter and continue working. Figure 21 displays a site layout map, illustrating not only the location of the access road but also the congested positioning of the two proposed additions.



(**Figure 21:** Site Conditions)

-Courtesy of RLPS, LTD.

To help eliminate overcrowding the entire site at once, the project team elected to begin construction on wing A several weeks prior to the initiation of wing B. Wing A is the addition located at the bottom of Figure 21, whereas wing B is located at the top. This sequencing permitted construction to begin at the back of the site and work its way to the front. Progression of work in this fashion helped utilize the site more efficiently, since it initially transformed the footprint of wing B into a viable space for workers to flow through. Figure 22 shows how work progressed from west to east along the length of the site. Another added advantage to the phasing of construction is that it offset the time in which large pieces of equipment were needed on site. On days in which cranes were required for wing B they were often not need for wing A. The implemented methodologies drastically improved the congested site conditions regarding the initial planning.

(**Figure 22:** Progression of Work Flow)

-Courtesy of Weber Murphy Fox, Inc.

Architectural Design:

The next largest constructability issue with Masonic Village at Sewickley is a result of the building's architectural design. Numerous protrusions and depressions along the structure's exterior façade creates an extremely labor intensive assembly for masonry workers. As phase 2 additions progressed, the project team quickly realized the layout of the building was simply not designed to be compatible with block construction. Dimensions between corners do not match up well with dimensions of standard CMU walls or brick veneer. A lot of time and cost has been associated with block modification needed to shave each unit down to its proper size. The project manager estimated there could have been a savings of almost $750,000 by simply laying out spaces to better accommodate the dimensions of masonry work. Figure 23 and 24 shows the irregular shape workers are faced with on the construction of the exterior façade.

In order to deal with this issue, the project team put in a request to the architect to physically alter certain measurements around the building's façade. No request was too drastic of an alteration and was commonly on the scale of a few inches. Change requests were just enough to avoid things such as having to cut each and every block all the way up every corner of the building. Other proposed changes in dimensions included minimal alterations to a few window opening sizes. The team determined the marginal benefit of a few minor modifications to certain sizes would be greater than leaving them as originally designed. To the benefit of the project team, the architect worked with them as much as they could to accommodate their requests. Although not every change was accepted, many of them did end up being employed and allowed for a better ease of constructability.

(**Figure 23:** Irregular Brickwork)

-Courtesy of Weber Murphy Fox, Inc.

(**Figure 24:** Uneven Façade)

-Courtesy of Weber Murphy Fox, Inc.

Prefabricated Balconies:

All elevated floor slabs used on the project are comprised of precast concrete planks. Each slab was prefabricated off site due to lack of storage space and trucked onto the job as needed. Upon arrival, a truck crane was used to lift the massive planks into position where they were grouted to load bearing masonry walls. Due to the nature of the building, precast planks are a very important part of the project schedule's critical path. The structure is erected by building one story of CMU walls, in which precast floor slabs are set on top of, and then repeated by adding another story of walls directly on top of the precast planks. Therefore, without the planks being put into position it is impossible to continue the structure upward. Figure 25 displays how the CMU walls rest on the precast slab below it.

As each floor slab was lifted into position, everything seemed to be going smoothly. However, when it came time to set the prefabricated balcony slabs the project team noticed a huge issue. The slabs that had been delivered for wing A of the addition were actually the wing B balconies. Unfortunately, construction of wing B lagged wing A by several weeks, making the balconies on site virtually useless to the project team at that point in time. The mix up accounted for 3 weeks of delay due to the lead time necessary to prefabricate the correct set of balconies for wing A. After weeks of waiting, the project team was plagued with even more bad news. As wing A balconies were being loaded for delivery, they were informed that the crane had accidentally dropped one of the planks and broke it in half. A new balcony had to be cast, creating an even greater burden on the project's timely development.

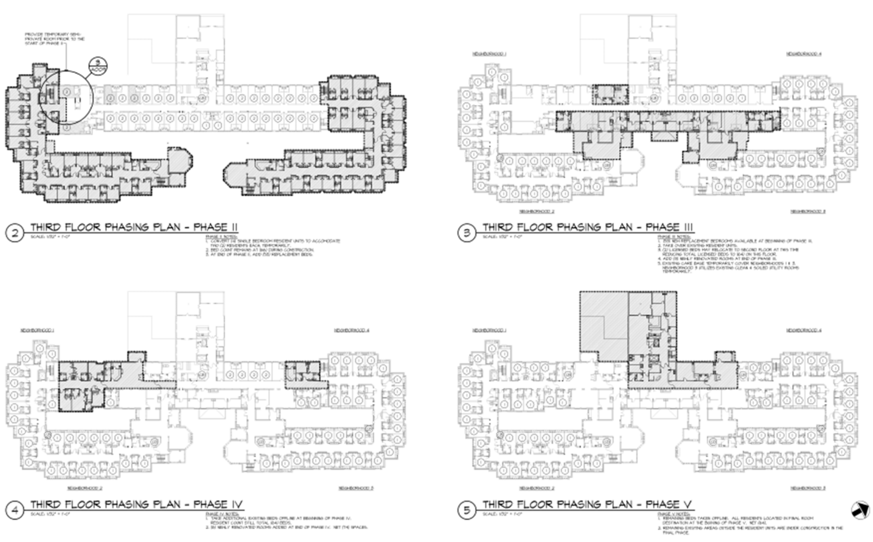
(**Figure 25:** Precast Balcony)

-Courtesy of Weber Murphy Fox, Inc.

In order to deal with an obstruction to the critical path, the project team did everything in their power to keep as much work flowing as possible. Although some portions of second floor CMU walls were able to begin, masonry workers were still limited in what they could accomplish. Furthermore, without being able to completely continue the structure upward there was very little that could be done to keep the project on pace. One of the best answers to the problem was to begin attaching brick veneer. The original schedule called for all three stories to be completed before attaching the brick façade. However, since work had been prohibited from continue upward and brick veneer was a necessary part of the watertight milestone, the project team decided it would be in their best interest for the veneer to chase the CMU blocks up the wall prior to total completion. This tactic permitted the team to regain some of their lost time and not take as big of a hit on the project schedule.

Schedule Acceleration Scenarios

The critical path for the project schedule contains numerous key activities throughout the construction process. Figure 26 shows the flow of work from phase 2 to phase 5. Starting with phase 1, the critical path moves from preliminary site work, to excavations, and onto pouring of foundations. Subgrade work includes caissons, grade beams, spread footings, and poured concrete walls. Phase 2 is where the majority of new construction takes place. The superstructure begins with the placement of 1^{st} and 2^{nd} floor slabs on grade, followed by 2^{nd} floor CMU walls. Precast concrete planks are lifted onto the walls, where 3^{rd} floor CMU walls are then positioned, and topped off with prefabricated wood trusses. Brick casing as well as windows and doors complete the watertight milestone and allow phase 2 interior fit outs to begin. Upon the conduction of several different inspections, which include food service, life safety, and nursing division, the critical path advances into phase 3. Phase 3 focuses on merely connecting the two additions back into the existing structure. The connecting segments of the building are both new construction and follow the exact same sequence of critical path events as conducted in phase 2. Phase 4 involves major renovations to the existing nursing facility due to the relocation of patient rooms. As the schedule advances, existing walls are demolished and reframed in different areas. MEP work is then redirected into newly built patient rooms, where finish work can proceed. As the critical path nears completion, the project advances into phase 5. Phase 5 involves light renovations to untouched regions of the existing building and is a very brief portion of the schedule. New finishes including GWB, painting, and flooring are the last major construction activities to be performed before the team completes its final punch list and close out.



(**Figure 26:** Phases 2-5)

-Courtesy of RLPS, LTD.

Weather is undoubtedly the most significant risk to the Masonic Village at Sewickley completion date. Given the nature of the project, construction is practically put on hold when rain and other forms of severe weather impose their presence. Since the majority of the superstructure is comprised of CMU bearing walls, heavy rain creates a scenario in which masons cannot achieve joints of adequate quality. Thus, the critical path is stopped and construction cannot progress. Despite the risk of weather delays being accounted for in the original schedule, the project team has found themselves in need of much more time than was initially planned for due to a combination of misfortunes. According to Project Manager Tony Grace, December of 2010 has been noted as being the harshest winter on record to date in the Pittsburgh area. Furthermore, this brutal season was followed by relentless amounts of rain throughout the spring and summer of 2011. Weather alone has been the sole constituent of causing the project to become roughly two months behind schedule. Since weather is an obstacle that cannot be controlled, there is nothing the project team can do other than let nature run its course and try to regain lost time once they have reached their watertight milestone.

The possible solution to the current delay in schedule would be to increase the total number of labor hours devoted to the project after the additions are finally enclosed. Once the structure becomes watertight, weather is no longer a driving factor and the team's biggest risk essentially becomes nonexistent. The CM at risk currently employs a 5 day, 40 hour work week. This could easily be increased to include evenings, weekends, or both. Utilizing around the clock work provides an opportunity for added hours to catch the project schedule back up to date with where it needs to be.

If extending the hours of the work week is difficult to accomplish, another practical alternative would be to simply increase the amount of man power present in the 40 hours of time provided. Crews of various trades currently on the job are fairly small compared to the amount of work that needs to be completed. Increasing the size of their work force has the potential to be extremely advantageous to the schedule. As opposed to completing work in one wing and moving to the other, contractors could establish active crews in both wings at the same time. Thus creating and end result of doubling the output in half the anticipated time.

Although both scenarios fulfill their respective roles in advancing the schedule, there are certainly added costs associated with each of them. Whenever more laborers are brought onto the job site, the total cost of wages will increase significantly. It is the construction manager's duty to keep these costs as low as possible. When employing a larger workforce, it is imperative to dictate how much and how often laborers are exposed to premium time versus typical wages. In order to keep costs low, it is valuable to employ more qualified laborers than having to pay overtime rates to a limited number of workers. If construction activity advances toward a longer work day, the project team may want to establish different shifts, in which different laborers work at different hours. The same principle would also hold true for weekend activity. The construction manager should mandate a maximum of 40 hours per week for each worker. Therefore, productivity on the project would drastically increase while simultaneously keeping overhead costs to a minimum.

Value Engineering

According to Project Manager Tony Grace, there was absolutely no need for value engineering on the Masonic Village at Sewickley project. Between previous building history and the time dedicated to actually planning the additions, years' worth of preparation and experience has been devoted to achieving an ideal structure on the first attempt. Masonic Villages of Pennsylvania is an organization that has been in business for over 130 years. Throughout the longevity of the company, the organization has established five separate campuses across the state of Pennsylvania. Although there are certainly subtle differences from campus to campus and building to building, each structure has generally maintained a common similarity in function and architectural design. The current additions and renovations to the existing nursing facility are nothing new to the organization. Therefore, the ultimate goal of the owner is to get things right on the first attempt and not expend additional time trying to find ways to value engineer their projects.

Masonic Villages of Pennsylvania is an owner that knows exactly what to expect from the construction process. The construction process is being overseen by a very experienced owner's representative. Every bid that was eventually awarded fell within the anticipated overall budget of the owner. Therefore, Masonic Villages of Pennsylvania was not forced to employ any sort of value engineering on the facility.

Throughout the life of the project, thus far only one value engineering idea has even been proposed to the owner. The proposal was issued from one of the project team's plumbing subcontractors. The idea was to change all subgrade plumbing lines from cast iron to PVC pipe. Nonetheless, the owner was not a proponent of the alteration and turned it down immediately. Masonic Village feels that since cast iron is a much more durable material than PVC, it should be the material utilized in the facility. They believe the marginal benefit of switching the type of pipe would not be greater than the marginal value. Therefore, it did not take much time for the organization to reject the first and only proposed value engineering idea.

Despite their history of resisting value engineering ideas, one concept that could have great benefit to the project is to value engineer the exterior masonry wall assemblies. Masonry is by far the most abundant and costly material used on site. Finding ways to maximize efficiency of use and minimize material waste would be an excellent concept to pursue. It would lower material costs for the owner as well as create a more environmentally sustainable form of construction.

Analysis #1: Masonry Acceleration

Problem Identification:

Masonry work is undoubtedly one of the most critical factors dictating the final completion date of the project. Between CMU's and brick casing, masonry is by far the most abundant and time consuming project activity. The building's entire superstructure is comprised of CMU load bearing walls. The current erection sequence progresses by forming one story of CMU bearing walls, which are topped with precast concrete planks, and followed by the next story of CMU bearing walls. Furthermore, the assembly is finished off with brick veneer that concurrently chases CMU erection up the wall. Tracking and documenting progress is a critical part of the construction process. Any part of the trade that becomes delayed would result in drastic implications to the final project completion date. Finding innovative ways to speed up the erection process could lead to weeks' worth of progress. Such improvements in work flow might be the best answer to regaining lost time from other activities as well.

Research Goal:

The goal of analyzing masonry acceleration is to conduct in-depth research on various methods and techniques that can decrease the overall time needed to perform the activity. Alterations will consider advancements in both direct and indirect masonry related activities. Researching different scenarios will help provide the best combination of construction practices that result in an efficient, yet quality controlled outcome.

Methodology:

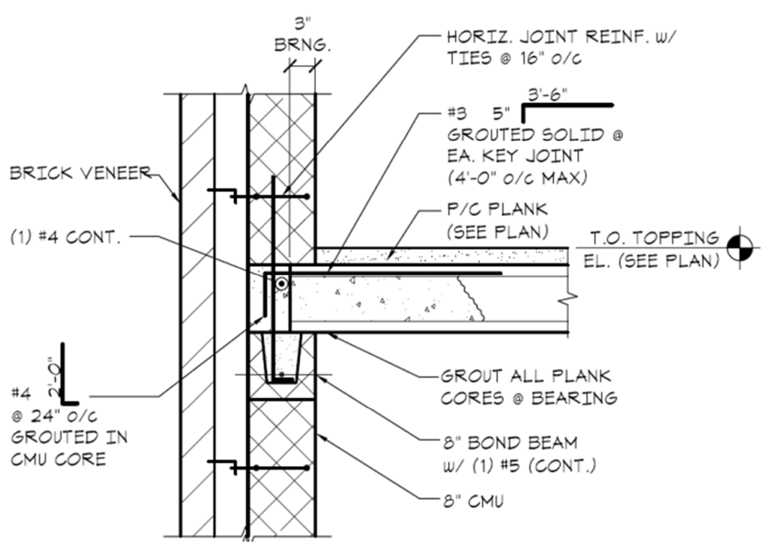
Background research in the following areas will provide a better understanding of the assembly process and form a solid perception of influential factors on durations:

- Get familiarized with other trades that may have an impact on the progression of masonry work
- Use the PM as a source for coming up with innovative ways to make changes
- Contact Weber Murphy Fox and use their experiences to identify alternative processes that would be implemented on similar projects in the future
- Interview masonry subcontractors on key procedures used in the field
- Compare data on various construction techniques/sequencing
- Understand the flow of work and expected timeframes
- Look into external factors that influence masonry work

Adjusting the Critical Path

In order to effectively accelerate the speed of in-place masonry work it is imperative to obtain a solid understanding of other activities that impact its progress the most. It is also necessary to have complete control over how such activities are sequenced and executed. Placement times of certain schedule activities, such as brick veneer, are not nearly as crucial to project development as activities like CMU load bearing walls. Given that CMU bearing walls reside on the facility's critical path, subsequent processes cannot begin until each preceding task is completed. Although it is an important procedure in reaching the project's watertight milestone, there is certainly some flexibility or 'float' days associated with brick casing.

The critical path for Masonic Village at Sewickley has been previously formulated such that CMU work is repeatedly halted at the top of each story to allow precast planks to be set. An interruption in work inevitably creates a timely delay before masons are able to continue production. Figure 27 provides a visual representation of how floor slabs are currently being connected to the exterior walls. Removing precast planks from being sandwiched between exterior bearing walls would effectively eliminate their critical path dependency and ultimately shorten the overall schedule. Masons would have the ability to erect exterior walls completely up the façade without being disrupted. This would allow for masonry and precast workers to function simultaneously, providing a newly designed support system is in place for them to do so. Moreover, developing a method for supporting the building's new floor slab system can be viewed more in depth in the report's ***structural breadth*** located on page 59.



(**Figure 27:** Existing Connection Detail)

-Courtesy of RLPS, LTD.

The most aspect of removing precast slabs from the critical path is the concept of shortening the overall project schedule. Durations for all precast activities can be seen as occurring concurrently with other tasks. Therefore, the amount of time needed to set the slabs should result in a shortened project schedule by an equal amount of time. Table 8 displays relevant information regarding durations used for precast crews to set and grout various floor slabs. All values were obtained from the project schedule prepared by Weber Murphy Fox. The information is broken down into two components. One set of values are used to represent time on a floor-by-floor basis, whereas the other set of values divide up durations according to their appropriate building wings.

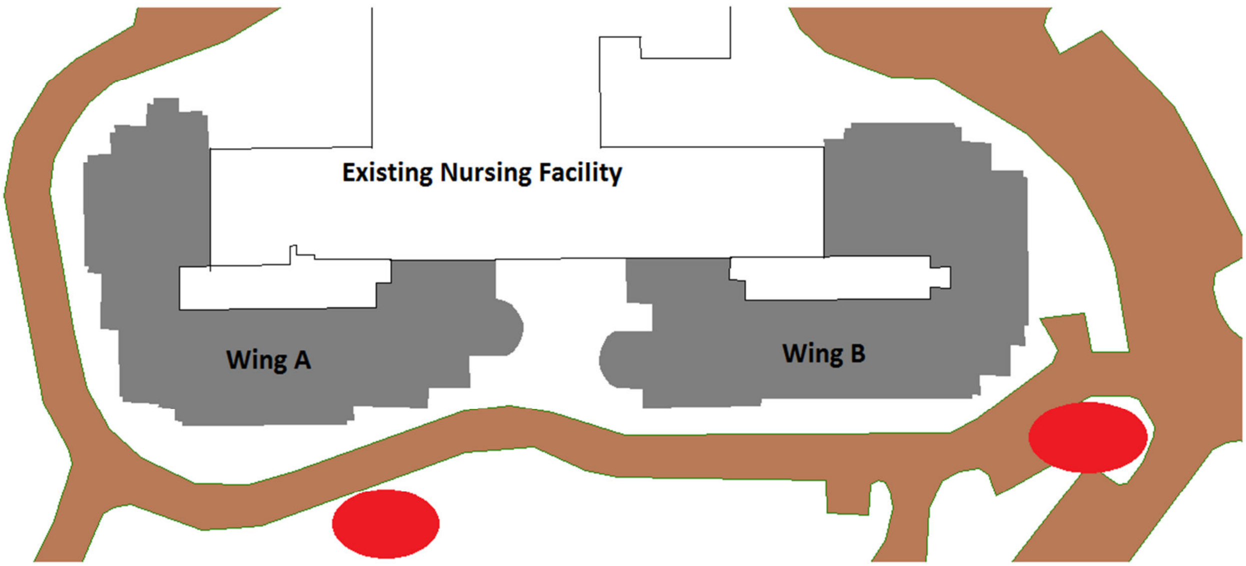
(**Table 8:** Durations of Precast Floor Plank)

	Wing A	Wing B	**Total**
Floor 1	0 Days	-	**0 Days**
Floor 2	6 Days	0 Days	**6 Days**
Floor 3	10 Days	10 Days	**20 Days**
Total	**16 Days**	**10 Days**	**26 Days**

Due to the configuration of the building, Wing A is the only region of the building that is designated as having a '1st Floor.' However, this area of the building takes advantage of a slab on grade and offers no opportunity for schedule acceleration in regards to precast planking. As the floor is placed for level 2, the duration of the activity is projected to take roughly 6 days to complete. However, this is because only part of Floor 2 actually requires planks to span over the existing region of Floor 1. The remaining portion of Wing A, as well as the entire portion of Wing B, also takes advantage of a slab on grade for Floor 2. Floor 3 is where the most significant savings in time is observed. It takes roughly 10 days to set and grout each wing. Therefore, a total of 20 days could be saved on Floor 3 between the two wings. The resulting decrease in schedule for the entire project would ultimately be **26 days**. Schedule benefits gained from employing such techniques far outweigh the cost of implementation. Using items like steel I-beams to support the structure's floor system can be viewed as a minimal expense when compared to over 3.5 weeks of project schedule reduction.

Mortar Mixing Procedures

One method of accelerating masonry work on the project is to properly plan and regulate how mortar is to be mixed. Appropriate placement of materials is an effective way to not only reduce the travel time of laborers but ultimately lower the activity's duration. Figure 28 shows the current locations of two sand piles on site used for mixing batches of mortar. Each time a new delivery arrives, trucks dump their loads in one of the two locations. It is then the responsibility of laborers to manually haul loads of sand around the jobsite. Masons on site are using several portable gas-powered mortar mixers. Therefore, the locations of mixing stations frequently fluctuate throughout the construction process. However, the mobility of their mixers certainly promotes a more rapid rate of production.

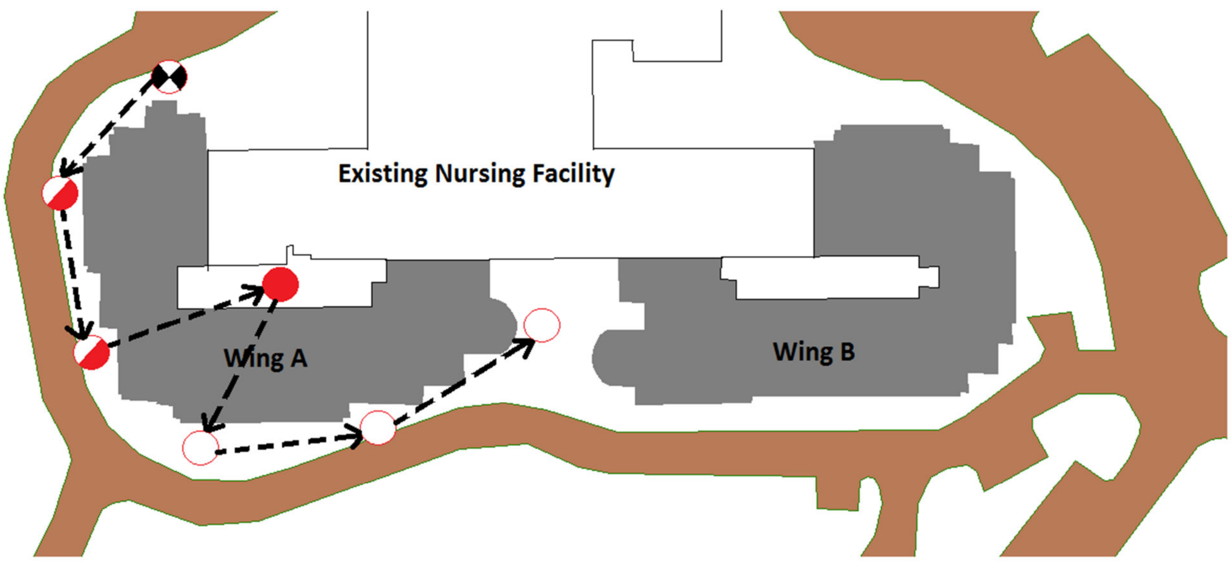


(**Figure 28:** Current Sand Pile Locations)

Due to the abundance of masonry on the project, it can be extremely beneficial to the schedule to investigate ways of reducing worker's travel time. Masonic Village at Sewickley contains roughly 180,000 units of brick veneer and approximately 115,000 CMU's, which account for interior, exterior, and subgrade blocks. Having to regularly haul loads of sand up to several hundred feet away with this much material to install, renders a fairly time consuming process. Considering the access road completely encompasses the structure, it seems feasible to employ a more systematic way of ensuring sand piles are near locations of mortar mixing. If construction progresses from left to right, delivery trucks could dump smaller loads of sand directly next to where work was presently being performed. Dumping sand immediately adjacent to current work areas essentially eliminates loading and travel time between batches.

Taking advantage of sand placement in this manner would free up time for additional laborers to concentrate on putting work in place as opposed to hauling materials.

In order for it to be effective to have delivery trucks dump loads of sand next to workers, it is important for the flow of work to proceed from left to right. As CMU walls are constructed, masons responsible for installing brick veneer need to simultaneously chase the flow of work across the building as well. This will allow previous sand piles to be fully consumed before new ones get dropped off at locations foreshadowing the work. There should be a minimum of two full mounds of sand at all times. However, it will most often consist of one full mound in front of the work that is lagged by two partial mounds being currently utilized. Therefore, construction planning needs to accommodate three pile locations at any given time. A graphical representation of the sand piles' leapfrog effect can be seen in Figure 29. New piles will first be used for CMU installation, whereas the remains from previous piles will be fully consumed by the brick casing crew. Once a pile is diminished, a truck will deliver a new load at the next location ahead of the CMU work.



(**Figure 29:** Leapfrog Effect of Mortar-Sand Mounds)

To establish the amount of time saved by the leapfrog effect, the distance from the massive original pile to each of the mini piles must first be examined. After distances have been resolved, the number of trips that would have otherwise been made to each location needs to be determined. The sum of each time interval is what constitutes the total savings.

According to Table 18 of Appendix F, 3 tons of sand provides enough mortar to lay 1,000 standard CMU's. This approximation assumes a 3/8" joint with a 1:3 mix by volume and accounts for a waste factor of 10%.

- 8”x8”x16” CMU = 0.889 SF
- 1,000 CMU’s x 0.889 SF = **889 SF of CMU / 3 Ton of Sand**
- 3 Tons of Sand = 4,000 Casement Bricks
- 3”x4”x8” Casement Brick = 0.167 SF
- 4,0000 Casement Bricks = 668 SF
- Through interpolation:
    - (668 SF / 3 Tons) = (889 SF / X Tons)
    - **889 SF of Casement Bricks / 4 Tons of Sand**

- *Therefore **7 Tons** of Sand = 889 SF of Wall Area (i.e. CMU **and** Veneer)*

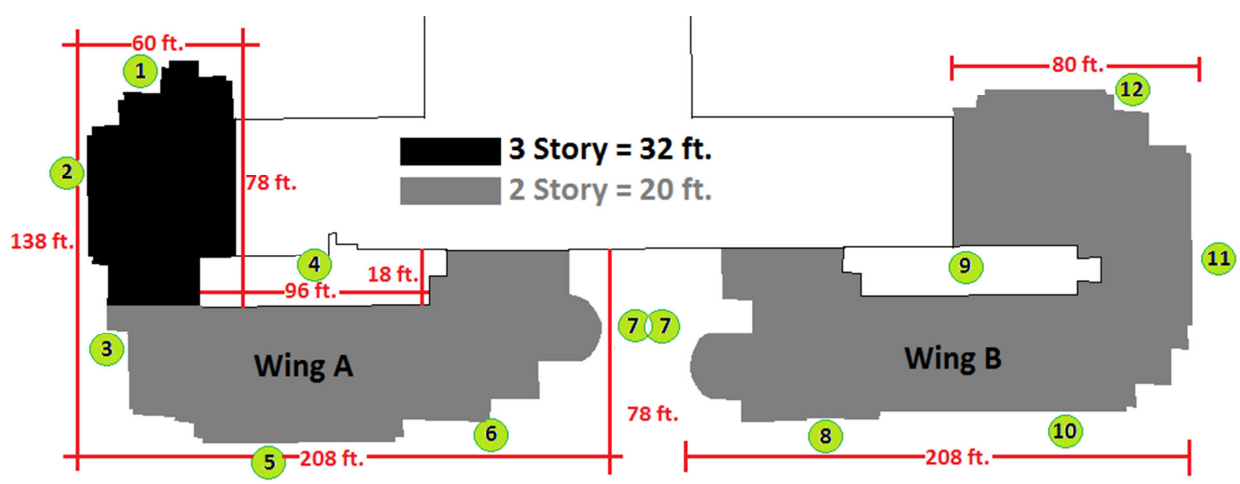
<u>3 Story Area:</u>

- 889 SF / 32 ft. = 28 ft. / 7 Tons of Sand
- **Use 14 Tons of Sand every 56 ft.**

<u>2 Story Area:</u>

- 889 SF / 20 ft. = 44 ft. / 7 Tons of Sand
- **Use 14 Tons of Sand every 88 ft.**

Figure 30 illustrates the height of the building for a specific area as well as approximate dimensions. The black region of the diagram represents the 32 ft. high 3 story portion of the building, whereas the gray region shows the 20 ft. high 2 story sections. Using the spacing determined for both the 2 and 3 story areas, Figure 30 depicts all of the 14 Ton sand mound locations and labels them sequentially in the order they will be dumped and utilized.



(**Figure 30:** Designated Sand Mound Locations and Sequence of Placement)

- Table 9 shows the approximate travel distance from original sand pile locations to each of the new mini piles. These distances are used to compute an average travel time, which is converted to hours based on the number of trips that would need to be made.

Assumptions:

- Sand = 30 pcf.
- Wheelbarrow Capacity = 6 cubic ft.
- Travel Rate = 3 mph

(**Table 9:** Difference in Travel Distance)

Pile Number	Distance From Closest Pile (ft.)	Round Trip Travel Time (s)	Time to Haul 14 Ton (hr.)
1	250	114	4.9
2	190	86	3.7
3	150	68	2.9
4	115	52	2.2
5	80	36	1.6
6	40	18	0.8
7	115	52	2.2
8	150	68	2.9
9	140	64	2.8
10	85	39	1.7
11	65	30	1.3
12	135	61	2.6
Total	**1,630**	**688**	**29.6**

Results:

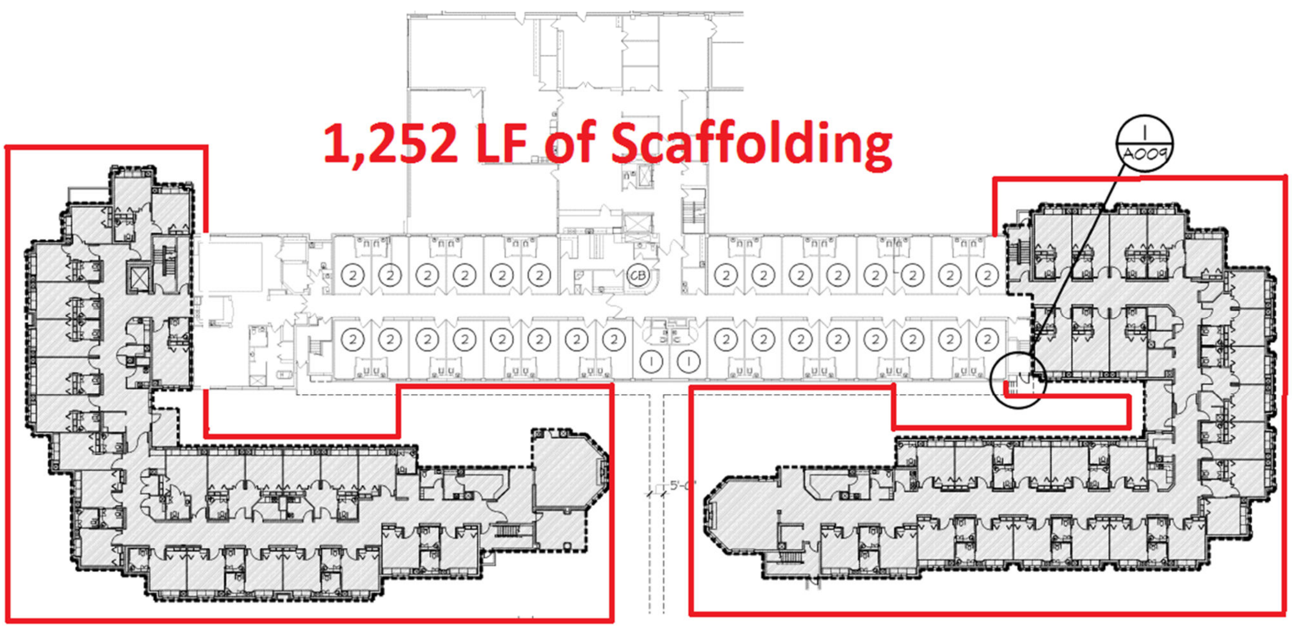
- 1 Ton = 2,000 lbs.
- 2,000 lbs. x 14 Ton/pile = 28,000 lbs./pile
- 28,000 lbs./pile x 12 piles = 336,000 lbs.
- 336,000 lbs. x (1 ft^3 / 30 lbs.) = 11,200 ft^3
- (11,200 ft^3 / 12 piles) x (1 Load / 6 ft^3) = 155 Loads/pile
- 155 Loads x 688 sec/Load x (1 min/60sec) x (1hr/60min) = 29.6 hrs.
- Total Time Savings:
    - 29.6 hrs. / (8 hrs./day) = **3.7 Work Days**

After running the numbers, it was observed that dumping the mortar-sand in multiple smaller locations had a drastic impact on the activity's total duration. Using a leapfrog method as opposed to hauling sand from its original location was far more efficient. It was observed that roughly **3.7 work days'** worth of labor was lost by simply having to move sand from one end of the site to the other when it was ready to be mixed.

Freestanding vs. Hydraulic Scaffolding

Despite being overlooked to some extent in the grand scheme of a building's construction, the selection and positioning of scaffolding may have a rather noteworthy impact on a project's schedule. Assemblies that are erected and dismantled on numerous occasions rapidly begin to prolong activity durations for trades like masonry. Proper construction planning is essential to minimize the time needed to setup and disassemble equipment on a larger scale. When evaluating different options for such procedures it is also valuable to have a solid understanding of the importance placed on cost and schedule. There are certainly some methods of scaffolding a building that are more efficient than others. However, such methods normally come at a higher cost to the owner or contractor. Therefore, a quicker setup may not be as valuable depending on the needs of the project. It is the construction manager's duty to evaluate each project independently and select the most appropriate method for a given set of circumstances.

At Masonic Village at Sewickley it is obvious that erection speed is a critical factor, given the abundance of masonry on site. Laborers utilize freestanding metal scaffolding throughout the construction process. Based on the importance of schedule, the project team elected to assemble scaffolding around the structure's entire perimeter, which sums up to be a total of 1,252 LF. The arrangement of which can be viewed in Figure 31.



(**Figure 31:** Current Location of Scaffolding)

-Courtesy of RLPS, LTD.

According to data provided by Weber Murphy Fox, there is 39,047 SF of above grade masonry that needs to be surrounded by scaffolding. Such a considerable amount of scaffolding reveals that equipment cost is of lesser concern than project schedule. The evidence becomes apparent when understanding that the project team does not want masons wasting time dismantling and relocating the system around the site. Nonetheless, an overabundant amount of scaffolding may prove to be an inferior method of accomplishing the job when compared to the effectiveness of hydraulic lifts. Despite their increased price, cost of the copious amount of scaffolding already being used may provide a perfect incentive to switch methods. It is well-known that hydraulic scaffolding is capable of generating a much faster rate of production. Loading blocks and mortar are a far less daunting task, as well as the means of simply raising and lowering workers' elevation. Data extracted from *RS Means Facility Construction Cost Data: 2011* (pg. 18) was used to run calculations regarding the time needed to assemble **AND** dismantle scaffolding:

- *Each of the following methods assumes a crew size of 4 workers.*

Free Standing Scaffolding:

- Labor rate of 356 SF/hr.
- 39,047 SF of coverage area
- Assembled and dismantled 1 time
- *Total Output:*
    - 109 Hours OR
    - **13.7 Work Days**

Hydraulic Scaffolding:

- Labor rate of 21 LF/hr.
- 1,252 LF of coverage length
- 1 unit = 64 ft. in length
- Assembled and repositioned 19 times
- *Total Output:*
    - 58.7 Hours OR
    - **7.3 Work Days**

After calculating the total amount of time solely dedicated to assembling and dismantling each form of scaffolding system, a total savings in time was computed. This figure is found by simply subtracting 7.3 work days from 13.7 work days. The result of the analysis shows a total savings of **6.4 work days** in the overall schedule. Since a typical work day contains 8 hours, there is a total hourly savings of 51.2 hours. When quickly contrasted with cost, the hydraulic unit is roughly 13% more expensive than a typical system. However, the significant reduction in the amount of labor hours associate with each would likely keep it as a worthwhile option.

Overall Schedule Reduction:

Making adjustments to the project's critical path by removing precast floor planks from between the structure's exterior walls seemed to provide the greatest opportunity for accelerating masonry work. Anytime large activities can be effectively erased from the critical path, one can expect to observe a rather significant boost to the schedule. Since it would take the precast crew a total of 26 days to place all of the planks, every trade following that activity would correspondingly be delayed by the same amount of time. However, offering a way to perform such work concurrently with other trades allows future work to begin up to 26 days sooner. Thus, the project's final completion date is shifted by an equivalent amount of time.

Altering the type of scaffolding system used by laborers accounted for the second most sizeable way to accelerate masonry work. Hydro-mobile scaffolding lifts are becoming increasingly popular on specific types of projects. Not only has the system been proven to be more reasonable on this particular project but it also allows for a more rapid rate of production through its ease of use. Despite actually being 13% more expensive, its use can still be justified through 6.4 days' worth of time savings.

Lastly, the mortar-sand mound study showed its significance through a highly calculation based analysis. It is shocking to discover that almost four whole work days of production is lost by simply having to haul loads of sand across the site. With a solution as simple as dumping loads of sand near areas where masonry work is being performed, it would be foolish to not try and recapture an extra 3.7 days' worth of time in the schedule. Although certainly the least effective part of the three studies, it would surely be the easiest one to implement in the field.

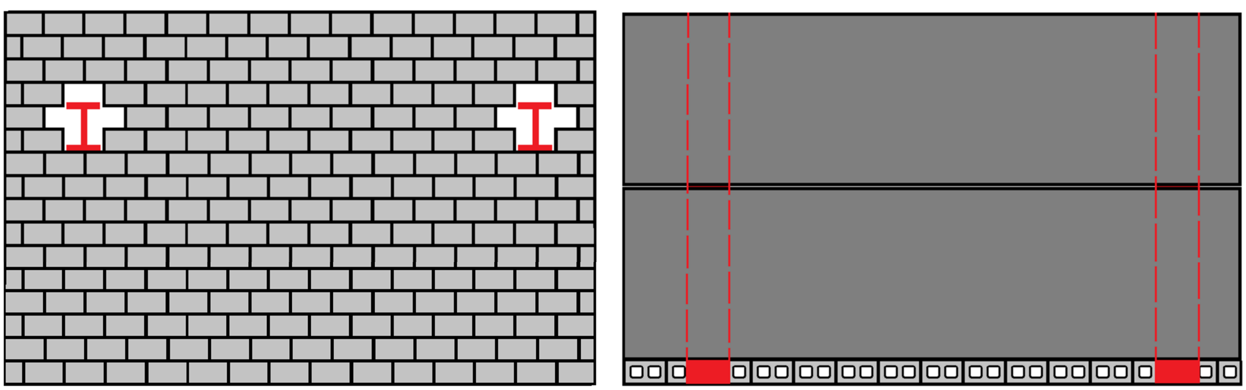
- *The following data provides the final results of Analysis #1: Masonry Acceleration*

Adjusting the Critical Path:	**26.0 Work Days**
Mortar Mixing Procedures:	**3.7 Work Days**
Freestanding vs. Hydraulic Scaffolding:	**6.4 Work Days**
Total Reduction in Schedule:	**36.1 Work Days**

Structural Breadth

In researching techniques to accelerate the speed of masonry work, the first major idea proposed was to remove precast planking from in between exterior walls. Nonetheless, producing a change of this magnitude ultimately creates structural implications for the building. Such modifications require a new means of supporting floor planks. Considering precast planks will no longer serve as an integral part of the wall system, steel wide flanges could create an effective alternative in providing the necessary support.

One of the most important things to notice when removing floor planks from a structural system is that they provide lateral stability for exterior walls. Therefore when being swapped with steel, it is necessary for member orientation to be perpendicular to the façade in order to regain lost stability. The newly proposed floor system should be designed to allow floor planks to span across them. Given the intent of Analysis #1 was to accelerate masonry bearing walls and not halt to set floor planks, mason's will need to leave openings in the walls for floor supports to be slid into and bolted down. Steel members will rest directly on top of exterior bearing walls and are attached to anchor bolts grouted within CMU cavities. All floor planks will have weld plates embedded on their undersides when they are fabricated. This will provide an easy way for welders to make a connection between steel supports and precast planks. Figure 32 shows an elevation and plan view of how the new support system will be constructed.



(**Figure 32:** Elevation & Plan View of Steel Support System)

- ***All Design Calculations can be Found in Appendix F***

Determining the feasibility of implementing such an idea requires calculations with respect to the longest distance being spanned. This distance is located along the facility's courtyard and resides over a set of dual resident rooms of style "semi-private type D." Type D rooms oriented longitudinally require steel members to span a distance of 25.5 ft. Although 10" hollow core planks are designed to span as much as 30 ft. between steel members, it would not be economical for one wide flange to support a tributary area of 30 x 25.5 ft^2. Therefore, beams within this portion of the building will need to be placed closer together. A spacing of 15 ft. was used for the calculations in Appendix F. However, other regions with smaller spans are certainly capable of reaching a max steel member spacing of 30 ft. A second critical thing to take note of is the floor to floor height. The distance between stories is 10'-4". Considering ceiling heights are 8'-0" and floor planks are 10" thick, the plenum space between floors is exactly 18". Such a small plenum height serves as somewhat of a restriction. Since the nominal height of W18 beams are greater than 18", all wide flange supports must be a W16 or smaller.

Upon using design criteria to calculate a factored load, the maximum shear and moment could be determined. Using the chart on page 3-123 of the *Steel Construction Manual: 14^{th} Edition*, a W14x90 beam was the most reasonable place to start the design process. Following further inspection of the Z_x Tables, the member was found to be insufficient. Its shape exceeds its limit for flexure. Therefore the most economical member listed higher in the table needs to be chosen. However, the member must be of size W16 or smaller due to height restraints. This means a W16x89 should be used to support the floor planks for 50 ksi steel.

Three things need to be checked before the W16x89 beams can be installed. These constituents are flexure, shear, and live load deflection. Flexure is certainly the most calculation intensive inspection and requires three different design checks. Assessments include web local buckling, flange local buckling, and lateral torsional buckling. Each criterion ensures the member will not fail in any of its three orthogonal directions. After the beam has successfully passed all three tests, shear capacity can be examined. It is typical for members to have a flexural failure long before they experience a shear failure. The shear capacity for these particular W16x89's far exceed the forces they are exposed to. The final assessment of the beam is for live load deflection. A simply supported beam exposed to a uniformly distributed load must have a deflection of $\Delta_{MAX} < 5wL/384EI$. If live load deflections are smaller than this value, the member is considered to be an acceptable beam.

Calculations in Appendix F show that a **W16x89** will pass all three beam checks. Therefore it possesses adequate strength to support the given design criteria. Considering beam design calculations were performed for the region of the building with the largest loads, it is feasible to implement the newly proposed floor system. If a W16 is able to support the heaviest portion of the building, there should be no problem specifying other members of size W16 or smaller to support lesser weights. As members experience smaller loads it would be economical to increase their spacing to accommodate the maximum span capacity of the floor planks. This will not only reduce the cost of construction but will also allow steel members themselves to perform at a more suitable level for their own structural capacities.

Analysis #2: Façade Dimensioning

Problem Identification:

Masonic Village at Sewickley's irregularly shaped façade has been identified as an exceptionally challenging and costly characteristic of the building. With numerous insets and protrusions around the perimeter, the building layout was simply not designed to be compatible with block construction. Considering measurements do not match up well with dimensions commonly used for masonry, laborers consume an enormous amount of time cutting blocks to fit their proper sizes. Nearly every corner requires blocks to be cut for each row, which repeats itself up the entire building. Modifying blocks to fit proper dimensions not only adds cost in material waste but also in time and manpower. This process has proven to become extremely time consuming and labor intensive. Making minor adjustments to exterior wall dimensions has the potential to generate an unprecedented cost savings. If dimensions are altered to matchup with standard CMU increments, there would be far less project cost associated with material waste, manpower, and time needed to perform additional masonry work.

Research Goal:

The intent of this study is to optimize savings for the owner by making minor alterations to façade dimensions. Adjusted measurements will be made on a scale of inches so as to not make extreme modifications to the layout of the building or the overall look of the façade. Cost savings in material waste, manpower, and time will be researched. Any expense associated with the irregularity of façade dimensions will contribute to the total cost savings being determined by each part of the analysis.

Methodology:

Background research will be performed in the following areas in order to fully grasp any effect various alterations have on the topics of interest:

- Extract measurements from project drawings and determine which dimensions need to be adjusted to better accommodate masonry work
- Research average wages for masonry workers
- Examine common practices and durations for cutting blocks
- Seek ways to reduce manpower without impacting productivity
- Explore how much time is needed to perform specific activities
- Interview tradesman to learn time saving techniques and methodologies
- Identify various block sizes available for construction
- Investigate expenses created by a given quantity of material waste

Analyzing Dimensional Mismatches

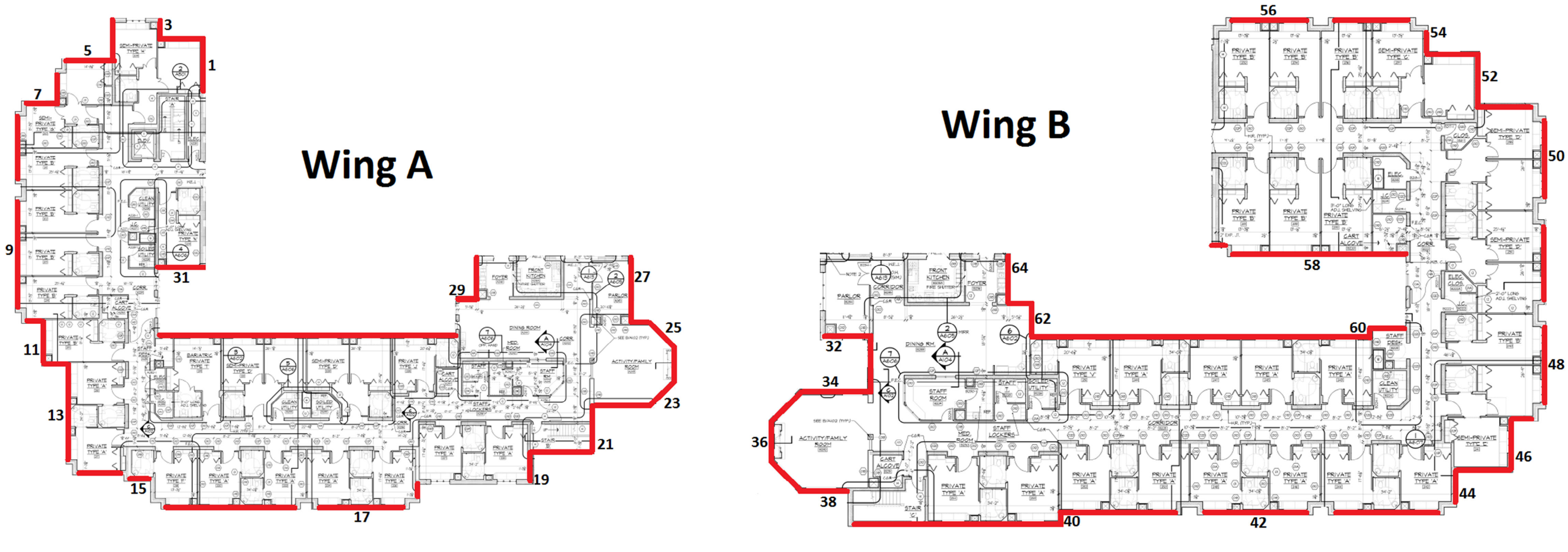
For the purposes of this analysis, adjusted wall dimensions are being altered only around the building's exterior façade. The maximum possible change that can be observed by any measurement will be within a range of ± 8 inches. This is based on the knowledge that standard CMU's being used on the project are roughly 16 inches in length. Modifications of this scale will ensure that all building dimensions become compatible with units appropriate for standard CMU construction. However, the real significance of this alteration is that it effectively eliminates the need to cut blocks for each row.

In order to locate an adequate starting point, all of the facility's façade dimensions for wing A and wing B need to be examined. Between both additions there are **116** different dimensional components along the exterior enclosure, all of which are constructed by masonry. Any length that evenly divides into multiples of 16 inches will be left as originally designed by the architect. Nonetheless, those distances that require CMU's to be cut at the end of a row are the primary focus of Analysis #2. Figure 33, which can be found on page 63, highlights every wall in both building additions that are ***NOT*** designed to evenly accommodate 16 inch increments. The illustration shows that 64 of the 116 different elements require some sort of variation to their specified measurements. This means that 55% of measurements for the entire façade are illegitimate for the scope of this study. Correcting this issue would offer huge advancements in the project's budget due to the massive price-tag already associated with masonry work.

It is also important to tabulate all data related to individual components after thoroughly examining each wall length. Such information can be used to compile studies involving a variety of different methods related to cutting project costs. A direct correlation exists between dimensional mismatches and the cost associated with material waste, time, and manpower. Understanding how each one impacts the others is a fundamental part of conducting a well-designed and accurate analysis.

Table 10 and Table 11, located on page 64, lists all 64 walls of interest. Table 10 presents elements located in wing A, whereas Table 11 charts those positioned in wing B. Based on currently defined measurements, each wall number is contrasted with the length of the final block needed to construct a distance of previously specified dimensions. Adjusted blocks greater than 8 inches will be extended to 16 inches, whereas ending units less than 8 inches will be reduced to 0. This will result in all corners of the façade being terminated by a complete CMU. Final block lengths noted in the tables will be used to determine how many CMU's need to be cut and the resulting amount of material waste. Since the newly proposed building measurements do not require blocks to be cut, the sum of all expenses associated with time and waste from the current method will represent how much cost could actually be saved.

- Figure 33 shows all 64 of the building's 116 exterior façade dimensions that are being modified. Each location is highlighted in red and labeled sequentially (1-64). Refer back to this figure to identify all wall numbers noted in the analysis.



(**Figure 33:** Walls to be Adjusted)

(**Table 10:** Length of Last CMU/Row Wing A)

Wall Number (Wing A)	Last Block Length (in.)
1	2
2	11
3	14
4	2
5	2
6	2
7	7
8	3
9	4
10	2
11	9
12	6
13	12
14	10
15	13
16	14
17	12
18	14
19	10
20	3
21	7
22	14
23	8
24	8
25	8
26	8
27	11
28	2
29	12
30	7
31	8

(**Table 11:** Length of Last CMU/Row Wing B)

Wall Number (Wing B)	Last Block Length (in.)
32	14
33	11
34	13
35	8
36	8
37	8
38	8
39	5
40	12
41	12
42	12
43	12
44	6
45	8
46	8
47	8
48	3
49	3
50	3
51	12
52	13
53	10
54	8
55	3
56	2
57	14
58	8
59	13
60	8
61	4
62	10
63	4
64	2

Material Waste:

One of the most import things to realize in regards to material waste is that the entire scrap from a cut block does not necessarily become 'waste.' Masons are often able to utilize suitable pieces of scrap for other regions of the building. Therefore, lengths of each ending block must be thoroughly analyzed to determine where standard **16" CMU's** will actually cause material to be wasted and where scraps can be put to use in other places.

To establish a conservative value, research should adhere to one key principle. This concept is based on the idea that 8" CMU's leave 8" of scarp, 9" CMU's leave 7" of scarp, 10" CMU's leave 6" of scrap, and so forth. For instance, if masons are able to utilize a 7" scrap in a location that requires a 7" block, the CMU only needs to be cut **one** time and **no** waste will be observed from that particular unit. However, it is also important to understand that masons typically only use the two ends of the block for construction. Therefore CMU's cannot be divided into three or more useable pieces. Given that dimensions of each final wall component vary in length, the following data displays the pairing of wall numbers in Figure 33 that are able to perfectly use the scrap generated by the other. These sets of walls are also formulated using information previously presented in the block length tables.

1,3	2,39	4,16	5,18	6,22	7,11	8,15	9,13
10,32	12,14	17,61	19,44	20,34	23,24	25,26	28,57
29,63	31,35	36,37	38,45	46,47	48,52	49,59	54,58

The outcome of such data sets offers an intriguing result. It can be inferred that 24 pairs, which represents 48 of the 64 wall elements being studied, generate virtually no material waste under original construction procedures. Thus only the remaining 16 wall components need to be analyzed in regards to a quantity of material waste.

It also follows that the remaining 16 wall elements do not necessarily generate large quantities of waste simply because they do not "perfectly" match up in 16" increments. Just because a 9" CMU produces 7" of leftover material, it does not mean the scrap must be used as a 7" block. For example, the unused portion of the CMU could be trimmed once again to accommodate the need for blocks of sizes 6" or less. Table 12 provides matchups for 10 of the remaining 16 wall components where such a scenario could possibly exist. Discarded material is created by cutting the scrap a second time and producing an even smaller piece of waste. The amount of waste per CMU formed by implementing such procedures is listed in the rightmost column of the table. Although this is where the first notable portions of material can actually be defined as "waste," quantities are fairly small due to the ability to continue reusing scraps produced from other blocks.

(**Table 12:** Scraps that can Still Accommodate Additional Walls)

Wall #	Length of Scrap		Wall #	Length of Last Block		Total Waste of CMU/row
21	9	=>	60	8		**1”**
27	5	=>	50	3		**2”**
30	9	=>	55	3		**6”**
33	5	=>	56	2		**3”**
40	4	=>	64	2		**2”**
					Total:	**14”**

Table 13 lists the remaining 6 walls being studied. These constituents produce waste in excess of what can be reused in other portions of the building. When CMU's are cut to length at the end of a row, the entire scarp becomes wasted material.

(**Table 13:** Waste from Remaining 6 Walls)

Wall #	Length of Last Block	Total Waste of CMU/row
41	12	**4”**
42	12	**4”**
43	12	**4”**
51	12	**4”**
53	10	**6”**
62	10	**6”**
	Total:	**36”**

Masonic Village at Sewickley contains standard 8” high CMU's for the entirety of the second and third floors. The first floor, which is partially below grade, is constructed with poured concrete walls and does not utilize CMU bearing walls. The ceiling to ceiling height of floors two and three are each 10'.

- 10 ft. x (12 in/ft.) = 120 in
- 120 in/floor x 2 floors = 240 in
- 240 in / (8 in/row) = 30 Rows of CMU's

- *Multiplying the total waste established in Table 12 and Table 13 by the number of rows of CMU's in the building will provide an overall quantity of waste.*

- 14 in + 36 in = 50 in (of waste/row of CMU)
- 30 Rows x 50 in/Row = 1500 in
- 1500 in x (1 CMU / 16 in) = 93.75 CMU's
    - The equivalent of **94 CMU's** become wasted material

As expected, the amount of material waste is exceptionally low when compared to the overall volume of masonry work on the project. There is an estimated 34,700 CMU's that make up the building's façade. Therefore 94 CMU's are only 0.3% of the total quantity of blocks. By comparing 94 wasted blocks to $312,400, for the cost of above grade 8" CMU work, there is an estimated savings of $937. An additional 10% should also be added as a waste factor for doors and windows, which increases the savings to **$1,031**. This is certainly a minor savings when compared to such a vast amount of work. However, a true reduction in project costs will be revealed through savings in time and manpower, each of which heavily corresponds to the material waste tables above.

Time and Manpower:

Worker's wages are by far one of the most costly portions of any project. Decreasing the number of laborers on site as well as the overall time needed to conduct a task can greatly benefit the budget. Masons that are given less intensive work to perform are able to reduce their crew sizes and ultimately their bid. Determining how much additional time and manpower is necessary to erect the structure as previously designed will present an answer to how much cost could be saved by way of the newly proposed changes.

As previously shown in Figure 33, there are 64 dimensional wall elements which require some sort of adjustment to a 16" CMU in each row. Following the prior explanation it was also observed that 24 pairs of walls, or 48 individual components, can perfectly use scraps created by the other. Such a scenario means that 24 CMU's only need to be cut **one** time to accommodate the ending blocks for one course of the first 48 different walls being studied. Therefore, the number of cuts needed to be made is easily calculable.

- 24 CMU's x (1 Cuts/Course) x 30 Courses = 720 Cuts

Scenario number two is carried out through the assistance of Table 12. It can be observed that 5 of the remaining pairs of walls produce a scrap that can also be implemented in others areas of the building. However, the difference with this situation is that scraps produced from elements in Table 12 are too large to perfectly matchup in other regions. Therefore, they need to be cut a **second** time to properly fulfill their roles in the wall.

- 5 CMU's x (2 Cuts/CMU) x 30 Courses = 300 Cuts

The third scenario observed during construction is displayed in Table 13. This table accounts for the last 6 wall elements being analyzed. Each constituent is comprised of a CMU's that produces a length of waste which cannot be implemented elsewhere. The final 6 wall elements have blocks that are cut just **one** time, leaving the remainder of the unit to become waste.

- 6 CMU's x (1 Cut/CMU) x 30 Courses = 180 Cuts

Assumptions:

- 4 min/cut (measure, load, cut, climb scaffolding, and put-in-place)
- 20% more cuts to account for windows and doors
- Labor rate of $28.00/hr.
- 10-15% increase in manpower

The following calculations show the number of CMU's or scraps of CMU's that need to be cut for the façade and how much cost is associated with it:

- 720 Cuts + 320 Cuts + 180 Cuts = 1,220 Cuts
- 1220 Cuts x 20% increase = 1464 Cuts
- 1464 Cuts x (4 min/cut) x (1 hr./60 min) = 97.6 labor hrs.
- 30 Masons x (10-15% extra manpower) = 4 Extra Workers
- 97.6 labor hrs. / 4 Extra Workers = 24.4 Extra hrs.

Cost of Additional Time:

- 24.4 Extra hrs. x ($28/hr.) x 4 Extra Workers = $2,733
- 24.4 hr. schedule delay x ($28/hr.) x 26 Original Workers = $17,763
- $2,733 + $17,763 = **$20,496**

Cost of Additional Manpower:

- (59 day duration x 8 hr./day) x ($28/hr.) x 4 Extra Workers = **$52,864**

Total Cost Reduction:

The cost associated with requiring additional manpower for block cutting had the largest impact on the project's budget. Four extra individuals were added to the crew size due to the needs of such labor intensive work. Over a duration of 59 days, labor rates of added workers proved to have costly implications. It cost the owner roughly $52,864 for masons to increase their crew size by four people. Given the newly proposed method of construction essentially eliminates having to resize CMU's, a four person increase in manpower would be virtually nonexistent. Therefore, the expense created by wage rates is viewed as a savings when the structure is altered to the proposed method of construction.

Analysis #2 revealed cutting or resizing over 1,400 CMU's encompassing the building's enclosure delayed the schedule by slightly more than 3 work days. Thus, additional costs are formed through an increase in time. It is implied that eliminating such avoidable work could have created an activity duration of 56 days as opposed to 59 days. A difference in schedule is an expense linked to the entire masonry crew. It costs $20,496 in labor to extend the task by 3 days, since the entire 30 man crew remains on site for that much more time.

The expense caused by material waste was surprisingly low. If masons are well organized and can optimizing their scraps, there will only be minimal costs caused by wasted material. On a job that contains hundreds of thousands of CMU's, a $1,031 material waste expense is almost negligible. However, it is important to realize the impact a zero waste structure has on labor. Such a reduction has the ability to ultimately create a ripple effect and generate a cost savings from a secondary level.

- *The following information presents a total opportunity for savings discovered in Analysis #2: Façade Dimensioning*

Cost of Additional Manpower:	**$52,864**
Cost of Additional Time:	**$20,496**
Cost of Material Waste:	**$1,031**
Final Cost Savings:	**$74,394**

Analysis #3: Value Engineered Façade

Problem Identification:

Understanding the importance of masonry work is critical to project development on this particular job. Considering 9% of the total cost of new construction is solely dedicated to the implementation of masonry work, exterior wall assemblies should be analyzed for value engineering opportunities. Design alterations that provide a savings in cost should be seriously considered. The shear abundance of brick work on site may allow even minor alterations to become an effective change on a larger scale. Furthermore, schedule impacts also need to be taken into account early during conceptual redesign processes. Some goals may not be worth pursing if newly proposed ideas prolong the project's schedule by too much. Nevertheless, most significant value engineering ideas are often largely favored by owners. On this project in particular, owner representatives are more concerned with a savings in cost than a delayed project completion date. Due to the fact there has been no value engineering performed on the project to date, there is certainly a potential for improvements to be made.

Research Goals:

The purpose of this investigation is to *value engineer* the facility's exterior façade. This process will primarily be performed through the use of embossed brick-faced CMU blocks. Brick-faced blocks provide aesthetics similar to that of brick veneer without incurring additional material and labor costs. These CMU's are stamped with various patterns and offer a variety of different painting and coloring options. Such alternatives produce exactly what owners would expect from a value engineered process. The method provides a look similar to that of the original design, but at a cheaper cost and does not sacrifice quality.

Methodology:

Background research will be conducted in each of the following areas to determine the value of a redesigned façade:

- Individual cost per unit of embossed bricks will be contrasted with typical costs for standard CMU's
- Coloring options/painting will be considered for the newly proposed wall system
- Differentiation in wall assembly, including benefits and impacts that may be experienced by the project's schedule
- Devise new methods of insulating that achieve an equal or greater R value
- Research further techniques for achieving adequate moisture protection for the newly designed wall assembly

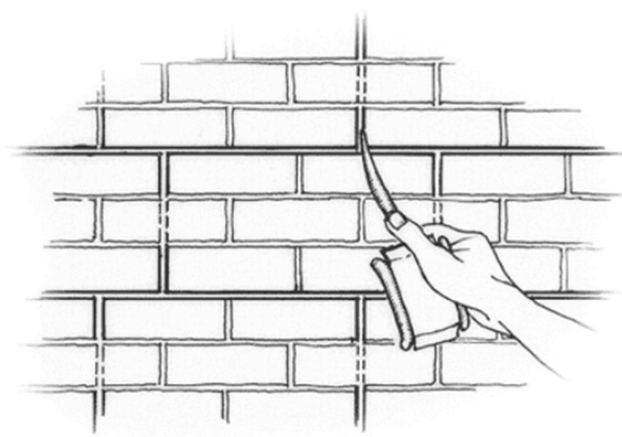
Performance of Brick Block

Much like standard CMU's, brick block is a precast concrete element often used for a variety of structural applications. It is capable of upholding the same basic functions as its standard CMU counterpart but with a more aesthetically pleasing appeal. Each CMU is imprinted with the look of six bricks in a running bond pattern. Three different vantage points of the unit are further illustrated in Figure 34. The purpose of the pattern is to manipulate the human eye into believing it is looking at casement bricks and not CMU's. Brick blocks allow for the implementation of aesthetically pleasing single-width assembly, while simultaneously providing the advantages of conventional CMU construction.

(**Figure 34:** Brick Block)

- Courtesy of Westbrook Block

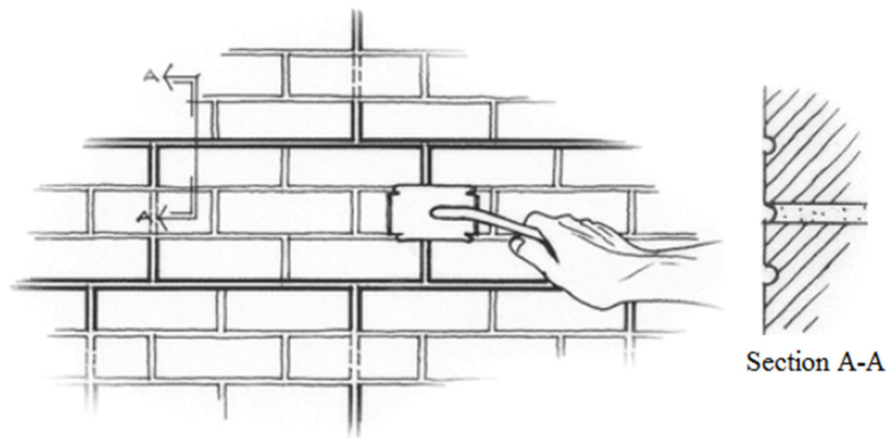
Differing from typical CMU construction, brick blocks require special attention to specific jointing techniques. Vertical and horizontal jointing is similar to what would be expected from typical masonry construction. A striking tool is used to remove excess mortar from around the exterior perimeter of each block. Nonetheless, one small difference arises in that it requires the middle third of units to be jumped over when striking a vertical joint. This is due to the six brick pattern displayed on the face of each CMU. Figure 35 details a more clear illustration of the reasoning behind striking vertical joints in this fashion.



(**Figure 35:** Vertical and Horizontal Jointing)

- Courtesy of Westbrook Block

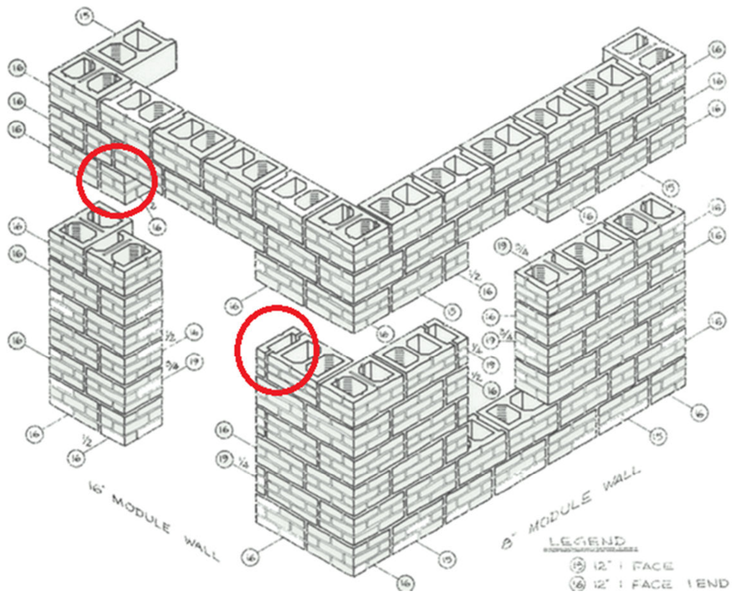
More experienced masonry laborers are required for establishing flush joints. Flush jointing is what creates the illusion of the pattern's two half "bricks" becoming one whole "brick" when joined together. Workers will require the use of a special utensil in order to achieve adequate quality. The tool shapes the mortar in that region of the CMU such that it is perfectly flush with the block's surface. The actions used to perform flush jointing can be viewed pictographically in Figure 36. Skilled workers are capable of making it extremely difficult to detect where the perimeter of individual CMU's are actually located.



(**Figure 36:** Flush Jointing)

- Courtesy of Westbrook Block

Brick block is available in five standard sizes, which include 4", 6", 8", 10", and 12". For the purposes of Analysis #3 all data will remain consistent with standard CMU's by using comparable 8" high blocks. The aesthetics created by a running bond pattern formed from larger sized CMU's has the potential to produce a sophisticated and labor intense assembly process. Much different from units such as split faced blocks, a running bond pattering is unique in that everything needs to be extremely precise. All architectural joints, whether they are precast or made from mortar, need to line up perfectly in both the horizontal and vertical directions. Such details would not be nearly as important with units like split faced blocks due to the random nature of their faces. In a world that does not always provide distances which evenly match up to 16" increments, the preciseness of brick faced blocks becomes particularly problematic. Units cannot simply be adjusted to any length without throwing off the alignment of vertical joints. Even if vertical joints are kept in check, there will likely still be regions of the wall in which some bricks appear to either be elongated or truncated due to size manipulations. Therefore, it is common for manufacturers to provide extensive detail on how to manage such situations. Regarding brick faced blocks in particular, it is necessary to cut them at their quarter points. It may further be essential to install multiple cut blocks in a given row in order to get architectural joints properly aligned around doors and windows. Figure 37 highlights how critically sized components make for an even flowing running bond pattern.



(**Figure 37:** Adjusting Blocks to Accommodate Doors & Windows)

- Courtesy of Westbrook Block

Dominant Idea Behind Cost Savings:

The primary pupose of switching the facility's façade to brick block is to reduce the cost of the assembly through value engineering. The purpose of value engineering is to provide cheaper assemblies that do not sacrifice the building's quality. The aesthetics of brick blocks offer an adequate substitute for veneer units without comprimising the external quality of the wall. Providing the units deliver a reduction in cost, brick blocks present a valuable opportunity to take advantage of a way to value engineer the project. The largest savings in cost will undoubtley come from the need to no longer add any sort of veneer to the wall. Brick veneer alone is an expense that accounts for **$453,800** on Masonic Village at Sewickley. This is an expenditure that can virtually be eliminated due to the nature of embossed brick-faced CMU's. When contrasted with external costs associated from altering the wall assembly, an overall savings can be compared to determine the effectiveness of implementing the change. Another type of savings to consider is a decrease in project schedule. There are 45 days built into the schedule dedicated to adding casement bricks. However, the project is not completely dependent on the completion of brick veneer to keep further progress from developing. Therefore, it would not be a direct savings of 45 days in the project's schedule. Nonetheless, the veneer is a pertainent part of achieving the watertight milestone. Nearly all window openings have casement bricks that need to be laid around sills before any windows can be installed. A correlation with schedule reduction provides an additional advantage to the goal of value engineering the building's façade.

Additional Changes/Expenses of New Façade:

- *All cost values used for Analysis #3 can be found in Appendix B.*

Cost of Brick Block:

It is certainly expected that precast units with an aesthetically pleasing appeal, such as brick block, will be more expensive than a typical CMU. This is something that needs to be taken into account when trying to determine the effective savings from a value engineered wall assembly. For the purposes of Analysis #3, the cost of material will remain consistent with standard 8" blocks. Since standard sized CMU's were used throughout the project, an analysis regarding 8" brick block will provide an easier form of comparison. The amount of above grade 8" CMU's used to form the exterior walls of the facility is 39,047 SF. Therfore, it can safely be assumed that the value engineered system will require an equivalent amount of brick block. True work in place for Masonic Village at Sewickley amounts to $8.00/SF. This figure includes material, labor, and waste. The total value of work for exterior CMU's is found to be $312,400. Proposing to swap standard CMU's with brick block should leave a project team to expect roughly a 15-20% increase in cost. It costs more for manufacturers to produce embossed blocks and thus raises the cost of material. Brick blocks also demand installation from masons with a higher skill level. More experienced workers are needed to properly align architectural joints when a large amount of block cutting is taking place on a job. According to *RS Means: Facilities Construction Cost Data 2011,* the cost of brick block is $9.51/SF. This is a 19% increase from the original method. When multiplying $9.51/SF by 39,047 SF the newly proposed assembly is found to be $371,300. The difference between an exterior wall made with standard CMU's as opposed to one built of brick block creates an additional expense of **$58,900**.

Coloring Options:

Due to the lack of veneer being added to the façade, the embossed brick-faced CMU's will need to undergo some sort of coloring option. The most common means of adding color effects to CMU's is through the use of powdered dyes. Powdered dye is a form of admixture that is introduced when individual concrete masonry units are being cast. The dye manipulates the color of the concrete and has the ability to create a wide variety of different colors and effects. Since the existing structure contains a dark red brick exterior, the new additions should have a matching look. *RS Means Facilities Construction Costa Data 2011* states that dyed units of a solid color adds $0.41 toward material cost. The added cost is fairly minimal and accounts for only a 5% increase in material cost. This means that 39,047 SF of exterior enclosure creates an additional **$16,000** in project costs. The entire price is considered a direct expense since the façade would not otherwise have a need to be colored. Although dyed masonry is certainly a viable alternative, it is not the only option for coloring.

Popular forms of moisture protection are silicon based water repellents. Water repellents are typically a clear coating, which leaves two different options open for coloring. Dyed CMU's as described above could be covered with a clear coating to achieve more natural looking CMU's or plain CMU's could be painted for a more artificial appearance. Cost data from RS Means indicates a total additional cost of $0.83/SF to paint exterior CMU walls. It costs $0.43/SF for a moisture resistant first coat and $0.40/SF for a second coat of regular paint. Both coats are applied with rollers. Once again, an extra cost for the new wall assembly must be multiplied by 30,047 SF. The added process of painting the façade would cost **$32,400** with labor included. Figure 38 shows the two different options for coloring the façade. On the left is a wall built from embossed brick-faced CMU's that has been painted and covered by a water repellent coating; whereas the right side displays the look of dyed CMU's.

(**Figure 38:** Painted vs. Dyed Brick-Faced CMU)

- Courtesy of Westbrook Block

Insulation:

The final component to consider in the façade redesign is how the assembly is going to be insulated. It is obvious through inspection that the original method for insulating the walls is no longer a viable option. The original design calls for rigid foam board insulation to be installed between CMU bearing walls and brick veneer. Given the newly engineered wall structure no longer contains veneer to encapsulate the insulation, it cannot be placed along the outer edge of the CMU's. One of the easiest solutions to this discrepancy is to utilize a type of insulation that can be inserted within the cavities of masonry units. Typical materials are either loose fill insulation, spray foam insulation, or Styrofoam inserts. Since thermal properties of 2" foam board contained in the original wall structure are specified to achieve a value of R-10, a material must be selected that can achieve an equal or greater value. Furthermore, the resistance previously created by the veneer and the effects of thermal bridging between CMU webs must also be considered. Considering these additional factors in total thermal resistance, makes spray foam insulation a worthy replacement. The material is more than capable of attaining a thermal resistance of greater than R-10 and helps account for any additional factors. Rigid insulation currently located around perimeter walls creates a project cost of $1.00/SF, making for a total cost of $39,000. Figures from *RS Means Facilities Construction Cost Data 2011* indicates spray foam insulation for an 8" CMU wall to be $4.32/SF. After multiplying this value by the total square footage of wall area, it is found to be $168,700. The difference between the new method of insulating creates an additional project cost of **$129,700**.

Value Engineered Façade:

Upon summing up the gains and losses amongst various components, a total savings could be determined. External factors researched in the analysis were changes that must also inevitably occur when altering the system to single row masonry construction. Therefore, it would not be a complete value engineering analysis if these constituents were not taken into account as well. Elements such as coloring options or insulation procedures ended up being a more expensive aspect of construction than initially designed. In the grand scheme of things however, they were minimal expenses when compared to the total savings. Table 14 arranges all data researched above in a way that displays the total savings from the façade change. It also breaks down the new façade into two different coloring options. A total savings has been calculated for each method, depending on which coloring option the owner finds more desirable.

(**Table 14:** Cost Difference of Value Engineered Façade)

VE Changes	Cost Difference (Dyed CMU's)	(Painted Façade)
No Brick Veneer	+$453,800	+$453,800
Brick Block CMU's	-$58,900	-$58,900
Dyed CMU's	-$16,000	-
Painted CMU's	-	-$32,400
Spray Foam Insulation	-$129,700	-$129,700
Total Savings:	**+$249,200**	**+$232,800**

Mechanical Breadth

The primary purpose of Analysis #3 was to value engineer the exterior walls of Masonic Village at Sewickley through the use of a façade redesign. When conducting the study several components were altered, including methods of insulation. Given the newly proposed assembly eliminated a need for brick veneer, implementing 2” foam board between CMU’s and veneer was rendered impossible. Therefore, differing methods of insulation needed to be considered. The goal of this study is to determine the best type of insulation that can achieve an equal or greater R-value than that of the previous façade.

Inserting insulation into the cavities of CMU’s is certainly the most logical way to go about insulating the facility. This is because there is no suitable way to insulate the exterior face of the CMU’s as previously done and insulating the interior face would compromise net usable floor space. Therefore, thermal resistance from within CMU cores is the only viable option. There are three practical ways of insulating CMU cavities. These methods consist of loose fill insulation, spray foam insulation, and Styrofoam inserts. Thermal flow properties across the façade may require the use of more expensive forms of insulation.

Previous Façade R-value:

The most notable loss of thermal resistance comes from the removal of 2” foam board located between the two types of blocks. Rigid insulation was located along the exterior face of the CMU’s and covered the entire surface. The R-value of the 2” foam board used on this particular projected achieved a rating of **R-10**. Another notable feature to consider is the veneer itself. Although casement bricks are largely considered to be very poor insulators, they do contain some sort of resistance to thermal flow. A standard red casement brick upholds a thermal resistance property of roughly R=0.2/in. This means that the resistance of each 16” CMU will have to make up for the missing 16 inches of casement bricks that were previously located in front of them. Calculations indicate an additional **R-3.2** is lost in the façade transformation.

- R-value: (0.2 / in) x 16 in = 3.2

The final thing to consider is something known as a mass-enhanced R-value. Although thermal mass and thermal resistance are two completely different properties, heavier materials have the ability to create what is known as an “effective R-value.” Adding thermal mass to the outside of a wall assembly functions as a giant battery for heat storage. Once outside air temperature drops below the inside air temperature, heavy materials release heat they have stored throughout the day. This occurrence effectively slows indoor temperatures from dropping or rising without the assistance of mechanical equipment and forms a mass-enhanced R-value. However, it is very important to note that enhanced R-values ONLY exist when outdoor temperatures fluctuate above and below indoor temperatures on a daily basis. For the climate of Pittsburgh, Pennsylvania designers would be optimistic to expect such temperature swings to occur 5 months out of a given year. Conservative values like this this for the given region may create a 4% increase in the assembly's effective R-value, which provides an additional resistance of **R-0.5**.

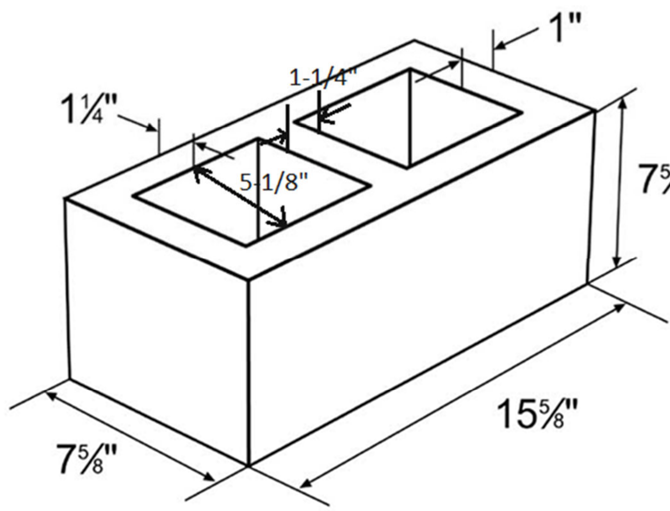
- R-value: (10+3.2) x 4% = 0.5

- *The effective R-value of the previous façade is calculated as follows:*
  - Total Effective R-value: (R-10.0) + (R-3.2) + (R-0.5) = **R-13.7**

Proposed Façade R-value:

It becomes apparent that the newly proposed assembly must achieve a value of R-13.7 or greater to ensure quality was not compromised by value engineering the façade. Spray foam insulation has the greatest potential to achieve the necessary thermal resistance and will be the type of insulation used for the assembly. Spray foam possesses an impressive material property of R-3.8/in. The thickness of the insulation will ultimately be limited to the size of the cavity. Figure 39 shows the maximum insulation thickness to be 5-1/8," which would provide a thermal resistance of **R-19.5**.

- R-value: (19.5 / in) x 5-1/8" = 19.5



(**Figure 39:** CMU Dimensions)

- Courtesy of 4erta.com

Although a resistance of R-19.5 seems like an acceptable alternative, the characteristics of the newly designed façade are significantly different from the old system. Since the new method of insulating does not completely isolate the wall, the effects of thermal bridging must be taken into account. It is important to note that web members of the CMU's interrupt the linkage of insulation between cavities. Whereas the previous method of insulation covered the entire exterior surface with 2" rigid insulation, the new method observed is disrupted by internal web members. The webs ultimately provide a less resistant pathway for heat to flow through. Referring back to Figure 39 shows a combination of the block's three web members makes up a total thickness of 3-1/4" along the CMU's length. This means that 20.3% of each block length has a direct thermal bridge between indoor and outdoor spaces. Standard CMU's, which are very poor insulators, contain a resistance value of **R-2.5**.

In order to figure out the average R-value across individual CMU's both web members and spray foam insulation needs to be considered simultaneously. Web members constitute 20.3% of each CMU's cross sectional length, whereas spray foam collectively spans a distance of 79.7%. A weighted average of the two percentages will provide the assembly's overall thermal resistance.

- Average R-value: [(R-19.5) x 79.7%] + [(R-2.5) x 20.3%] = **R-16.0**

The results of the study show that inserting spray foam insulation within CMU cavities is capable of attaining the necessary resistance. The previous façade possessed a value of R-13.7, whereas the proposed façade is capable of achieving a thermal resistance of R-16.0. Insulation methods utilized for the value engineered façade actually proved to be a slight improvement to the facility's ability for thermal containment. Given spray foam has shown to be a sufficient substitute, the newly proposed façade can be utilized without a concern of compromised quality as a result of the change.

Proposed Façade vs. Previous Façade:

R-16.0 > R-13.7

Analysis #4: Masonry Sustainability

Problem Identification:

Sustainability of design is a critical issue currently facing the construction industry. With an ever growing amount of public activism, society continues to move toward a culture that wishes to counteract the effects of greenhouse gas emissions and global warming. Considering buildings are the number one contributor of greenhouse gas emissions, there is no better place to start taking action. Many highly renowned organizations, such as college campuses, are taking the initiative to require all new construction to be sustainable in design. Such roles of leadership will hopefully set precedence for others to follow. Even if new buildings do not achieve a LEED rating, any form of ecofriendly construction is a step in the right direction. It is imperative for the construction industry to promptly act on the situation for the betterment of future generations. On Masonic Village at Sewickley, masonry is the most abundant material used on a pound per pound basis. Therefore, taking action in regard to sustainable aspects of masonry construction has the potential to reduce emissions as well as potentially earn LEED points for the project.

Research Goals:

The goal of sustainability in masonry is to explore construction methods and techniques that would allow for a more environmentally friendly design. All methods employed will also be analyzed under the LEED rating system to determine if improvements are worthy of earning additional points for the facility. Given the facility is already capable of achieving LEED Silver, a conscientious approach toward masonry work may earn enough additional points to upgrade the project's status to LEED Gold.

Methodology:

In order to conduct research for Analysis #4, the following procedures will need to be performed:

- Research USGBC requirements for earning LEED points through brick commercial construction
- Understand the present conditions of the project and decide where improvements can be made
- Determine which LEED points the project can obtain with minimal cost and effort
- Consider other actions that do not lead directly to LEED points but may be considered as ecofriendly improvements
- Conduct a final analysis to consider all improvements made

LEED Points

The USGBC has developed a rating system known as LEED that is composed of four distinct levels. From lowest to highest these ranks consist of certified, silver, gold, and platinum. Each status is based upon the amount of "LEED points'" a project earns. Processes must be in accordance with environmentally sustainable procedures defined by the USGBC. Any given project has the opportunity to earn up to a total of 110 possible points. Earning 40-49 points satisfies a rating of LEED Certified, 50-59 points qualifies for Silver, 60-69 points ranks at Gold, and 80+ points will earn Platinum standing.

Masonic Village at Sewickley is already on pace to achieve a rating of LEED Silver, as displayed by the total points earned on the score card in Figure 40. A complete scorecard for the facility according to *LEED 2009 for Healthcare: New Construction and Major Renovations* can be viewed in its entirety in Appendix E. A point's total of 55 lands the project well into the range of LEED Silver. Strategically implementing sustainable processes in regards to masonry work may add valuable points to the building, considering the accumulation of 5 more points would boost the project's status to LEED Gold. Any points that can easily be secured should certainly be sought after by the project team.

		N	Credit 1.1	Regional Priority: Specific Credit	0
		N	Credit 1.2	Regional Priority: Specific Credit	0
		N	Credit 1.3	Regional Priority: Specific Credit	0
		N	Credit 1.4	Regional Priority: Specific Credit	0
Sil		55	Total	Possible Points:	110

Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110

(**Figure 40:** Current Number of LEED Points)

- Extracted from LEED Scorecard in Appendix E

There are three different classifications within the LEED scoring system in which a building has the ability to earn points through its masonry. Categories of the LEED scoring system that may be affected by masonry work include *Sustainable Sites*, *Energy and Atmosphere*, and *Materials and Resources*. It is also important to note that certain categories are able to offer more points to the project than others. Nonetheless, these goals do not always end up being the most practical targets to pursue. Point chasing needs to be evaluated on a job by job basis. It is often not worth spending copious amounts of time and money on an objective that may only offer one or two additional LEED points. The easiest points to attain are frequently the more superior goals to pursue when trying to achieve the next level of LEED accreditation. In order to improve Masonic Village at Sewickley's rating, each of these three categories needs to be evaluated for the best opportunities available.

Sustainable Sites

The durability of masonry as a material allows for an exceptionally long lifecycle when compared to other construction resources. Its longevity ultimately seems like a natural fit for various aspects of sustainable sites. Using the material for brick masonry pavement or open celled masonry pavers has the potential to improve a project's LEED scorecard by up to three additional points. Each point is the result of 1 out of 3 different credits within the category. Analyzing individual credits will provide further knowledge on practical improvements for the site. The three potential points that can be earned through the use of masonry from the sustainable sites category are as follows:

- Credit 6.1: Stormwater Management – Quantity Control
- Credit 6.2: Stormwater Management – Quality Control
- Credit 7.1: Heat Island Effect (Non-Roof)

Credit 6.1, which deals with quantity control of stormwater, seeks to improve site sustainability by reducing the pollution of natural water sources. The permeability of brick pavers significantly decreases stormwater runoff. Filtration of water through masonry removes any contaminants that might be present. Credit 6.2 also deals with stormwater but in regards to quality control. The goal of this credit is similar to that of credit 6.1. However, it aims to provide ecofriendly treatment options. Utilizing porous pavements is a common practice for removing any phosphorous or suspended solids that may exist in the water. Although both of these credits are easily achievable, they do not offer any additional LEED points. Masonic Village at Sewickley already takes advantage of an extremely intensive stormwater management system and has already earned points for these credits.

The only remaining credit available in this category is for the reduction of heat island effect. The key to credit 7.1 is that it deals with non-roof portions of the site. A decline in heat island effect lessens the site's influence on local human and wildlife habitats. One LEED point is allotted for the installation of open-grid paving methods. In order to earn the point, the paving system must be less than 50% impervious for at least 50% of the site's total parking lot area. This is something that can be accomplished quite easily with masonry.

A LEED point for *Credit 7.1: Heat Island Effect (Non-Roof)* is certainly a viable option for Masonic Village at Sewickley. Throughout the lifecycle of the project, site development already accounts for the relocation or addition of roughly 50% of the facility's parking lots. Since large regions of the site are going to be reconstructed anyway, a simple change order for installing open-grid paving as opposed to an asphalt system would earn the project **1 LEED point**. Pursing such an option is a simple way of becoming one step closer to achieving the next level of LEED accreditation.

Energy and Atmosphere

In order for masonry to earn LEED points on this portion of the scorecard, blocks must harvest and store onsite energy. The energy should create a net decrease in demand from the facility's HVAC system. Points are often achieved through the use of passive solar designs. Heat energy absorbed by masonry in the afternoon can be stored for a reasonable length of time. Brick's ability to store such energy offers a free method of heating when outside temperatures drop below inside temperatures. A reverse scenario also holds true for cooling loads. Masonry units uphold an exceedingly high thermal mass and therefore contain a large resistance to thermal heat flow. This inherent property helps separate interior zones from the environment. Isolation of interior spaces moderates temperature swings during peak energy hours. The ultimate goal of sustainable masonry strategies within the energy and atmosphere category is to reduce the overall size of the HVAC system.

- *The following item is the only credit within the energy and atmosphere category in which masonry can earn LEED points:*
  - Credit 1: Optimize Energy Performance

Credit 1 of energy and atmosphere is intended for buildings to attain superior levels of energy performance. Improvements will result in HVAC systems operating above and beyond existing precondition standards. Between one and nineteen LEED points are offered for any sort of energy optimization that enhances the nursing facility's existing conditions by 5-50%. Nevertheless, the focus of Analysis #4 is to determine how to optimize energy performance solely by means of masonry. Criteria for LEED points are gauged on the reduction of energy cost and operating condition of the building's mechanical equipment.

Based on data utilized in the mechanical breadth, the thermal mass of masonry units for Masonic Village at Sewickley provides a 4% increase in thermal optimization. Employing methods that increase this number to 5% would deliver one additional LEED point to the project. Rough calculations indicate a reduction in window sizes would provide enough additional thermal mass to attain the necessary 1% jump. The building already contains rather large windows, which suggests a significant energy loss. The total area of the façade is 39,047 SF, whereas the total area of windows is 4,592 SF. Adding the two together provides a total enclosure area of 43,639 SF. This shows that windows account for 10.5% of the building enclosure's performance. Reducing the area to at least 9.5% would shift the percent difference to optimize the energy toward the masonry enclosure. When multiplying 43,639 SF by 9.5%, it is discovered that the total window area needs to be 4,146 SF. The resulting area indicates a window size reduction of exactly 10%. Considering the facility was designed with rather large window sizes, a 10% reduction not only earns the project **1 LEED point** but would still provide an ample amount of lighting for its occupants.

Materials and Resources

Materials and resources is the final category on the LEED scorecard in which masonry can contribute points to the building. Masonry has the ability to influence 11 out of 13 points in this particular category. There are three separate ways in which the material can benefit the project. The easiest method is for contractors to buy locally manufactured blocks and reduce pollution caused by transportation. A second technique involves recycling all debris that is not going to be used on site. This will ultimately keep as much material as possible out of landfills. Lastly, contractors can reuse old materials. If parts of a building are being demolished, the CM should ideally reuse as much of the old material as possible before ordering new items. All three of these constituents play a role in the construction process in which masonry has the ability to take advantage of.

- *Potential credits for materials and resources are as follows:*
  - Credit 1: Building Reuse – Interior and Exterior Walls
  - Credit 2: Construction Waste Management
  - Credit 3: Resource Reuse
  - Credit 4: Recycled Content
  - Credit 5: Regional Materials

The first potential point to be earned in this category falls under building reuse. Phase 4 of the project is designated for major interior renovations of the existing nursing facility. Both wings of the additions are solely dedicated to the relocation of resident rooms. After these rooms are relocated, old resident rooms are demolished and replaced with social gathering spaces. Several interior masonry walls will be deconstructed in lieu of these spaces. Credit 1 is intended to conserve resources by extending the lifespan of current building materials. Up to one point can be earned by reusing 50% of demolished interior walls. This is certainly a feasible task given interior walls are simply being moved around within the existing facility. The idea of reusing blocks from interior walls is something that should certainly be pursued by the project team, whom will be rewarded with **1 LEED point**.

Credit 2 is another noteworthy item to pursue. Construction waste management is dedicated to keeping construction debris out of landfills. Brick packaging is often insignificant. Units are typically delivered to a site with minimal branding and possibly a few wood slats used for protection. However, the durability and small unit size of bricks offers an even greater alternative for credit 2. In many instances bricks can be utilized as infill behind walls. Wing B of Masonic Village at Sewickley calls for a rather lengthy, 12’ high ivany wall due to the building being positioned on a hillside. Nearly the entire region under the first floor requires a large volume of infill for this space. There is more than enough capacity within this region for all unused brick to be utilized as infill material. Not allowing any masonry to enter a land fill would justify the full **2 LEED Points** for the construction waste management credit.

The last three credits in which masonry can earn LEED points are resource reuse, recycled content, and purchasing regional materials. Resource reuse takes advantage of salvaged products in an effort to diminish the need for virgin materials. Earning points for recycled content is as simple as management instituting some sort of mandatory recycling plan for the job. Last, it is important to buy local materials to reduce transportation pollution. Although masonry can achieve each of these credits, they will not *add* points to the scorecard for this particular project because they are already being carried out on site.

Transformation to LEED Gold

Masonic Village at Sewickley currently stands at 55 total points with a rating of LEED Silver. The opportunities listed above are techniques that can be employed to attain an additional **5 LEED points**. Carrying out these activities will provide the project with 60 LEED points and advance the building's status from LEED Silver to **LEED Gold**. Table 15 displays a summary of the facilities current standing as well as potential areas of improvement.

(Table 15: Easily Attainable LEED Points)

LEED 2009 for Healthcare: New Construction and Major Renovations

Category	*Possible Points*	*Current Total*	*Potential Points*	*New Total*
Sustainable Sites***	18	11	+1	12
Water Efficiency	9	7	-	7
Energy and Atmosphere***	39	20	+1	21
Materials and Resources ***	16	6	+3	9
Indoor Environmental Quality	18	11	-	11
Innovation in Design	6	0	-	0
Regional Priority Credits	4	0	-	0
Total:	**110**	**55**	**+5**	**60**

**** Denotes categories in which masonry is capable of earning LEED points*

Recommendations & Conclusion

Throughout the 2011-2012 Penn State academic year, a project has been studied involving additions and renovations to a nursing facility located on the Masonic Village at Sewickley campus. Research first began by gaining a solid understanding of the facility's existing and newly installed systems. Three technical reports on the facility included aspects like building systems, project schedules, cost analyses, and conditions related to the site and client's needs. Upon obtaining a thorough understanding of the building, four research analyses were proposed to try and improve the overall quality of the building and construction processes. These topics included:

- Schedule Acceleration Methods
- Construction Cost Reductions
- Value Engineered Assemblies
- Sustainable Designs

Succeeding in-depth research on each of the topics above the following conclusions have been determined:

Analysis #1: Masonry Acceleration

Three separate approaches were evaluated when trying to determine how to reduce the duration of masonry work. The most significant of these techniques suggested adjusting the schedule's critical path by removing floor planks from between masonry bearing walls. Once a floor of walls had been erected, masons were delayed a total of 26 days before they could begin forming other walls. This is a considerable time savings and is worth pursuing another means of structural support for floor slabs. The second part of the analysis described mortar mixing procedures and laid out a plan for reducing the schedule by leap-fogging sand mound locations. Although it proved to have a 3.7 day schedule reduction, it is likely not worth the site space or the hassle caused for the project team. Lastly, the difference between freestanding and hydraulic scaffolding was examined. A change in equipment produced a 6.4 day savings. Depending on how pressed for time the project team becomes, hydro-mobile scaffolding is a viable alternative but should be thoroughly contrasted with added construction cost.

Analysis #2: Façade Dimensioning

Out of 116 different dimensional elements encompassing the building's façade, 64 measurements do not terminate with even 16" increments. Therefore, an enormous amount of time and effort was exhausted from cutting and fitting blocks to their proper dimensions. Three different constituents played a part in creating added project costs. These participants included manpower, time, and material waste. Even though hundreds of blocks needed to be cut, material waste ended up being surprisingly low. Most scraps were able to be reused in other locations and did not end up becoming waste. The real expense was associated with labor. The added time and manpower required to shape each block accounted for a longer than necessary schedule. Labor rates for this duration created tens of thousands of dollars in additional costs. By adjusting building façade dimensions on a scale of inches, $74,000 could be saved. Design teams working on similar buildings in the future should highly consider this option for their projects.

Analysis #3: Value Engineered Façade

With masonry being the most abundant material in the entire building, finding ways to value engineer such systems has the potential to produce enormous cost savings. Brick block CMU's proved to be a great way to reduce project costs without compromising quality. Their aesthetic design completely eliminates the need for brick veneer. Therefore, $450,000 in the budget that had previously been dedicated to veneer installation quickly becomes a savings by the project team. The downside to this alteration is that masonry units, coloring options, and insulation all become more expensive activities. Nevertheless, the amount of money saved by eliminating the need for veneer far outweighs added cost in other areas. Employing the newly proposed façade has the potential to save about a quarter million dollars in the long run.

Analysis #4: Masonry Sustainability

The final topic analyzed involved finding sustainable means of construction for the most prevalent material on site. There are three different categories in which masonry can earn LEED points on the LEED 2009 for Healthcare scorecard. Categories include sustainable sites, energy and atmosphere, and materials and resources. Upon investigating particular requirements set by the USGBC, five points between the three categories appeared to be relatively simple credits to earn. Conveniently enough, the facility's scorecard indicated it was only five credits away from achieving a rating of LEED Gold. Simple adjustments outlined in Analysis #4 should definitely be considered by the project team in an attempt to advance the facility's status for the owner.

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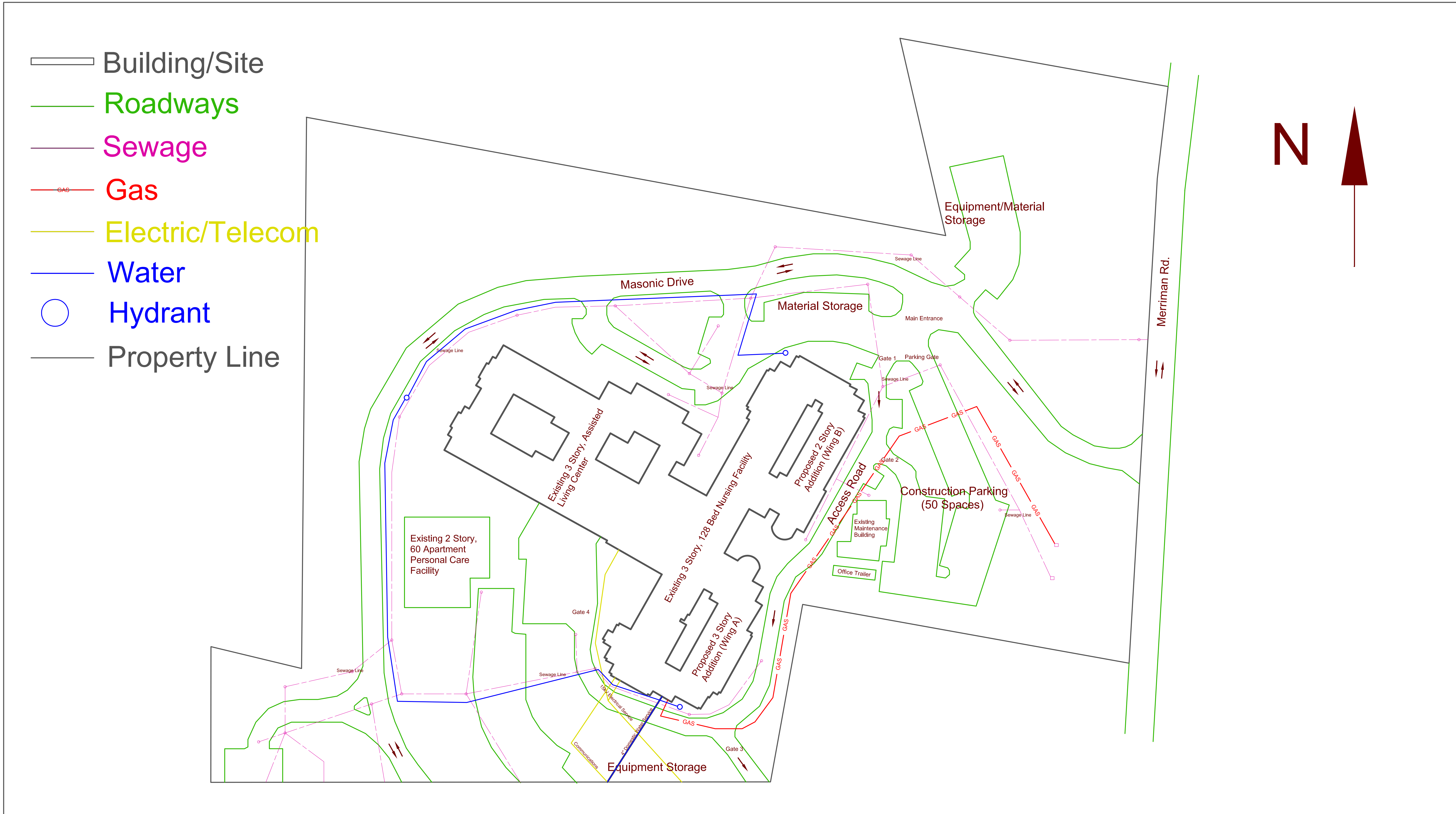
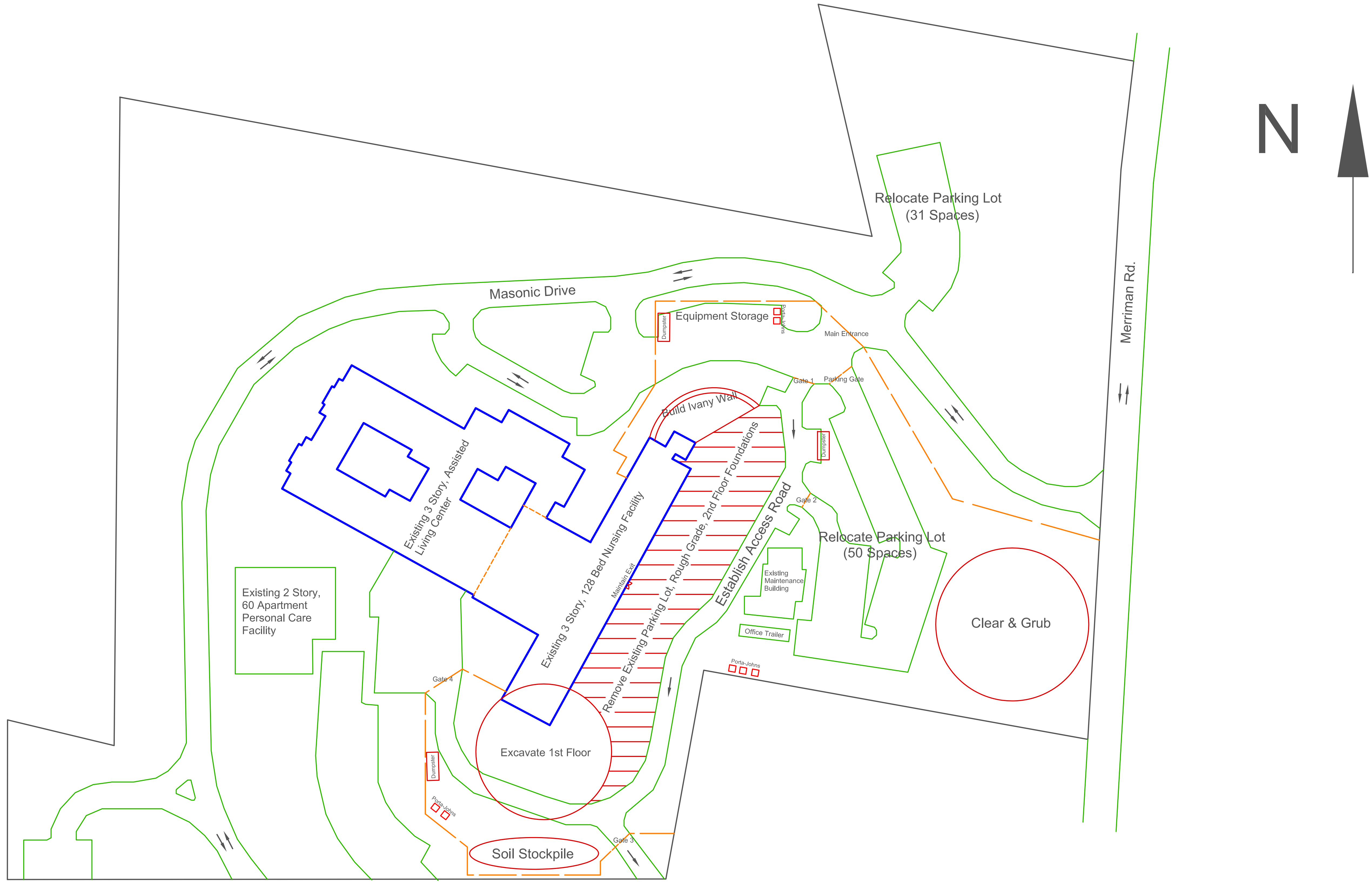
Appendix A

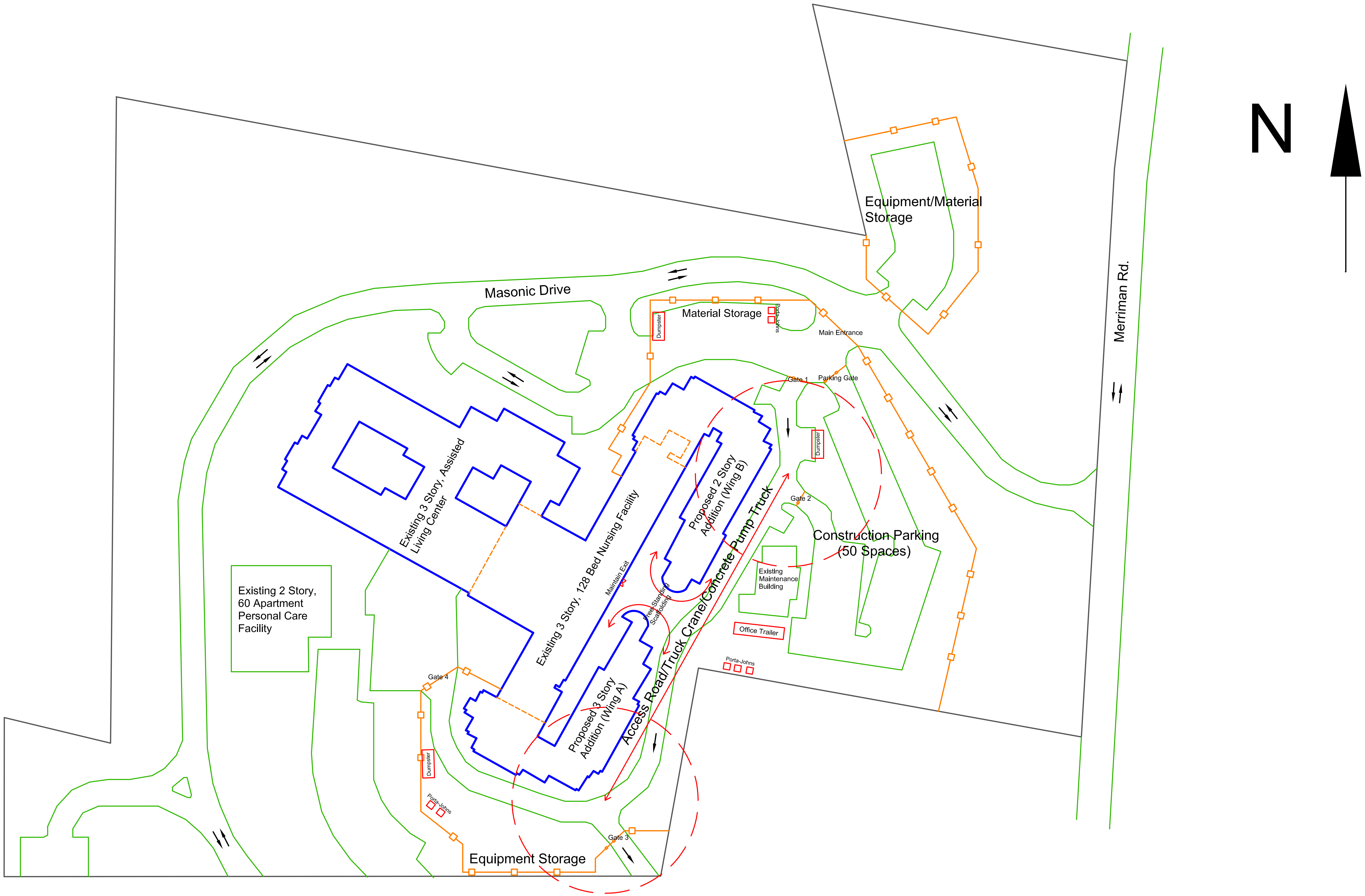
Site Utility/Layout Plan



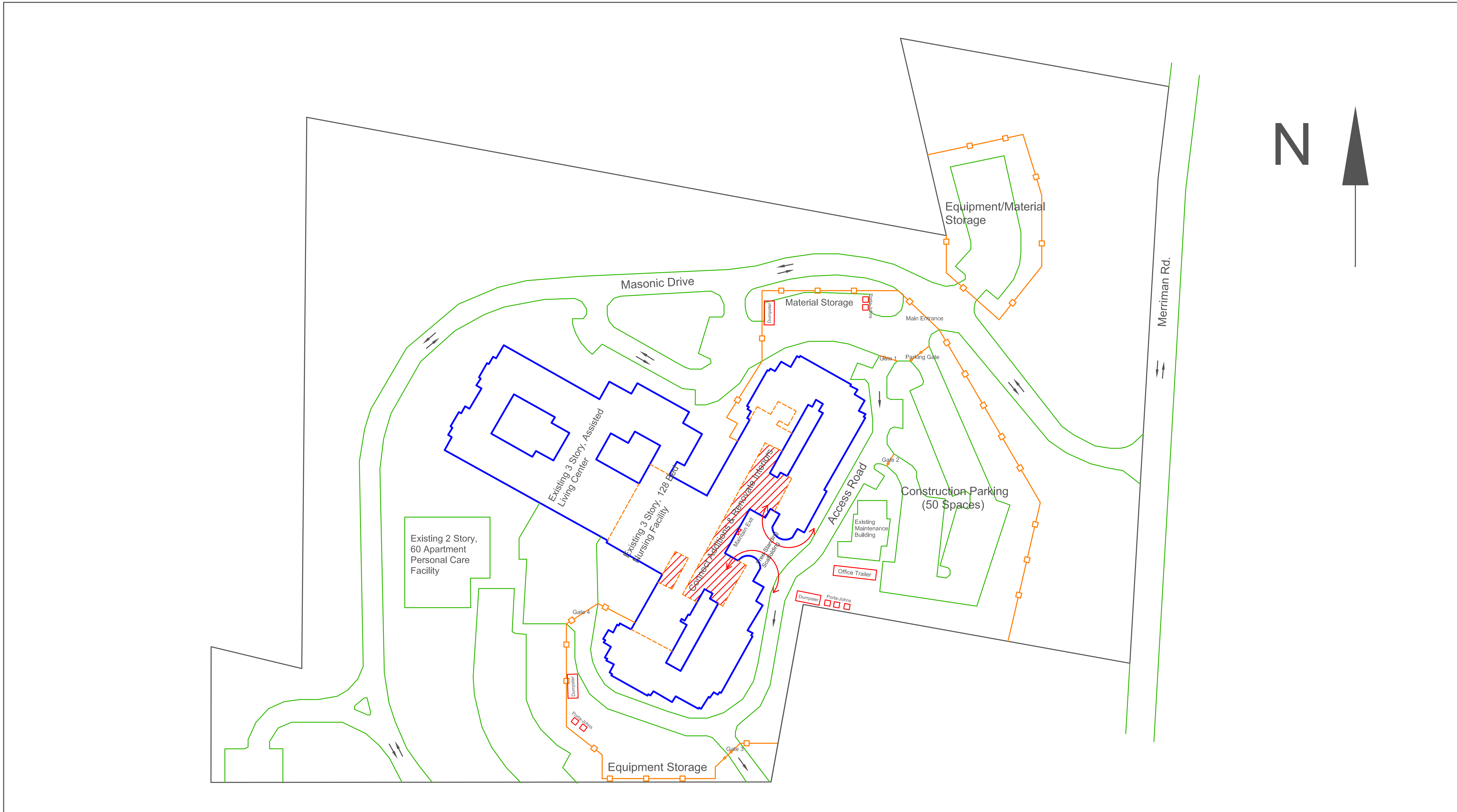
Masonic Village at Sewickley	Site/Utility Plan	9/23/2011	Jason Drake



Masonic Village at Sewickley	Layout Plan Phase1	9/23/2011	Jason Drake



Masonic Village at Sewickley	Layout Plan Phase 2	9/23/2011	Jason Drake



Masonic Village at Sewickley	Layout Plan Phase 3	9/23/2011	Jason Drake

Appendix B

RS Means Cost Data

Square Foot Estimate Data:

COMMERCIAL/INDUSTRIAL/ INSTITUTIONAL | **M.450** | **Nursing Home**

Costs per square foot of floor area

Exterior Wall	S.F. Area	10000	15000	20000	25000	30000	35000	40000	45000	50000
	L.F. Perimeter	286	370	453	457	513	568	624	680	735
Precast Concrete Panels	Bearing Walls	218.85	209.40	204.60	**196.70**	194.15	192.25	190.90	189.90	188.95
	Steel Frame	222.40	212.95	208.20	200.25	197.70	195.85	194.55	193.50	192.60
Face Brick with Concrete Block Back-up	Bearing Walls	208.25	200.30	196.25	189.90	187.85	186.25	185.15	184.30	183.55
	Steel Joists	212.40	204.40	200.35	194.00	191.90	190.35	189.30	188.45	187.70
Stucco on Concrete Block	Bearing Walls	199.00	192.30	188.90	184.00	182.25	181.00	180.10	179.40	178.80
	Steel Joists	203.15	196.45	193.00	188.10	186.40	185.15	184.25	183.55	182.95
Perimeter Adj., Add or Deduct	Per 100 L.F.	16.00	10.65	8.00	6.40	5.30	4.65	4.10	3.55	3.20
Story Hgt. Adj., Add or Deduct	Per 1 Ft.	3.90	3.35	3.10	2.45	2.35	2.25	2.15	2.05	2.05

***For Basement**, add $30.45 per square foot of basement area*

The above costs were calculated using the basic specifications shown on the facing page. These costs should be adjusted where necessary for design alternatives and owner's requirements. Reported completed project costs, for this type of structure, range from $84.90 to $212.80 per S.F.

Common additives

Description	Unit	$ Cost
Beds, Manual	Each	830 - 2825
Elevators, Hydraulic passenger, 2 stops		
1500# capacity	Each	59,700
2500# capacity	Each	62,900
3500# capacity	Each	65,900
Emergency Lighting, 25 watt, battery operated		
Lead battery	Each	299
Nickel cadmium	Each	785
Intercom System, 25 station capacity		
Master station	Each	3125
Intercom outlets	Each	176
Handset	Each	485
Kitchen Equipment		
Broiler	Each	4050
Coffee urn, twin 6 gallon	Each	3325
Cooler, 6 ft. long	Each	5275
Dishwasher, 10-12 racks per hr.	Each	5075
Food warmer	Each	530
Freezer, 44 C.F., reach-in	Each	3275

Description	Unit	$ Cost
Kitchen Equipment, cont.		
Ice cube maker, 50 lb. per day	Each	1825
Range with 1 oven	Each	3275
Laundry Equipment		
Dryer, gas, 16 lb. capacity	Each	915
30 lb. capacity	Each	3625
Washer, 4 cycle	Each	1100
Commercial	Each	1475
Nurses Call System		
Single bedside call station	Each	325
Pillow speaker	Each	265
Refrigerator, Prefabricated, walk-in		
7'-6" high, 6' x 6'	S.F.	173
10' x 10'	S.F.	137
12' x 14'	S.F.	121
12' x 20'	S.F.	107
TV Antenna, Master system, 12 outlet	Outlet	325
30 outlet	Outlet	208
100 outlet	Outlet	200
Whirlpool Bath, Mobile, 18" x 24" x 60"	Each	4950
X-Ray, Mobile	Each	14,700 - 83,000

RS Means Square Foot Cost Data: 2011 (Page 172)

Assemblies Estimate Data:

HVAC

3020 110	Heating System, Fin Tube Radiation	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
Heating systems, hydronic, fossil fuel, fin tube radiation				
Cast iron boiler, gas, 80 MBH, 1,070 S.F. bldg.		12.99	14.21	27.20
169 M.B.H., 2,140 S.F. bldg.		8.20	9.05	17.25
544 M.B.H., 7,250 S.F. bldg.	RD3020 -010	6.45	7.70	14.15
1,088 M.B.H., 14,500 S.F. bldg.		5.80	7.55	13.35
3,264 M.B.H., 43,500 S.F. bldg.	RD3020 -020	5.05	6.70	11.75
5,032 M.B.H., 67,100 S.F. bldg.		5.70	6.80	12.50
Oil, 109 M.B.H., 1,420 S.F. bldg.		15.10	15.55	30.65
235 M.B.H., 3,150 S.F. bldg.		8.25	9.05	17.30
940 M.B.H., 12,500 S.F. bldg.		6.30	7.25	13.55
1,600 M.B.H., 21,300 S.F. bldg.		6.35	7.20	13.55
2,480 M.B.H., 33,100 S.F. bldg.		6.40	6.85	13.25
3,350 M.B.H., 44,500 S.F. bldg.		5.75	6.90	12.65
Coal, 148 M.B.H., 1,975 S.F. bldg.		10.95	8.60	19.55
300 M.B.H., 4,000 S.F. bldg.		8.65	7.40	16.05
2,360 M.B.H., 31,500 S.F. bldg.		6.50	6.85	13.35
Steel boiler, oil, 97 M.B.H., 1,300 S.F. bldg.		12.35	12.75	25.10
315 M.B.H., 4,550 S.F. bldg.		6.05	6.45	12.50
525 M.B.H., 7,000 S.F. bldg.		7.45	7.45	14.90
1,050 M.B.H., 14,000 S.F. bldg.		6.65	7.45	14.10
2,310 M.B.H., 30,800 S.F. bldg.		6.45	6.90	13.35
3,150 M.B.H., 42,000 S.F. bldg.		6.30	7	13.30

RS Means Assemblies Cost Data: 2011 (Page 319)

D3030 115	Chilled Water, Cooling Tower Systems		COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOT
1300	Packaged chiller, water cooled, with fan coil unit				
1320	Apartment corridors, 4,000 S.F., 7.33 ton		5.98	7.68	
1600	Banks and libraries, 4,000 S.F., 16.66 ton	RD3030 -010	11	8.45	
1800	60,000 S.F., 250.00 ton		7.40	6.75	
1880	Bars and taverns, 4,000 S.F., 44.33 ton		19.50	10.70	
2000	20,000 S.F., 221.66 ton		18.70	8.85	
2160	Bowling alleys, 4,000 S.F., 22.66 ton		12.90	9.25	
2320	40,000 S.F., 226.66 ton		10.40	6.35	
2440	Department stores, 4,000 S.F., 11.66 ton		6.85	8.35	
2640	60,000 S.F., 175.00 ton		6.65	6.15	
2720	Drug stores, 4,000 S.F., 26.66 ton		13.55	9.55	
2880	40,000 S.F., 266.67 ton		10.35	7.20	
3000	Factories, 4,000 S.F., 13.33 ton		9.40	8.05	
3200	60,000 S.F., 200.00 ton		6.60	6.50	
3280	Food supermarkets, 4,000 S.F., 11.33 ton		6.75	8.30	
3480	60,000 S.F., 170.00 ton		6.55	6.15	
3560	Medical centers, 4,000 S.F., 9.33 ton		5.80	7.60	
3760	60,000 S.F., 140.00 ton		5.30	6.25	
3840	Offices, 4,000 S.F., 12.66 ton		9.10	7.95	
4040	60,000 S.F., 190.00 ton		6.40	6.40	
4120	Restaurants, 4,000 S.F., 20.00 ton		11.50	8.60	
4320	60,000 S.F., 300.00 ton		8.35	7	
4400	Schools and colleges, 4,000 S.F., 15.33 ton		10.35	8.30	
4600	60,000 S.F., 230.00 ton		6.80	6.50	

RS Means Assemblies Cost Data: 2011 (Page 324)

Electrical

D5010 120	Electric Service, 3 Phase - 4 Wire		COST EACH	
		MAT.	INST.	TOTAL
0200	Service installation, includes breakers, metering, 20' conduit & wire			
0220	3 phase, 4 wire, 120/208 volts, 60 A	960	920	[illegible]
0240	100 A	1,150	1,100	[illegible]
0280	200 A	1,875	1,700	[illegible]
0320	400 A	4,425	3,125	[illegible]
0360	600 A RD5010 -110	8,275	4,225	[illegible]
0400	800 A	10,200	5,100	[illegible]
0440	1000 A	12,400	5,850	[illegible]
0480	1200 A	15,800	6,000	[illegible]
0520	1600 A	27,800	8,600	[illegible]
0560	2000 A	30,600	9,800	[illegible]
0570	Add 25% for 277/480 volt			
0580				
0610	1 phase, 3 wire, 120/240 volts, 100 A	535	1,000	[illegible]
0620	200 A	1,100	1,475	[illegible]

RS Means Assemblies Cost Data: 2011 (Page 354)

D5020 208	Fluorescent Fixtures (by Type)		COST PER S.F.	
		MAT.	INST.	TOTAL
0520	Fluorescent fixtures, type A, 8 fixtures per 400 S.F.	2.71	5.50	[illegible]
0560	11 fixtures per 600 S.F.	2.56	5.35	[illegible]
0600	17 fixtures per 1000 S.F. RD5020 -200	2.47	5.25	[illegible]
0640	23 fixtures per 1600 S.F.	2.25	4.97	[illegible]
0680	28 fixtures per 2000 S.F.	2.25	4.97	[illegible]
0720	41 fixtures per 3000 S.F.	2.18	4.97	[illegible]
0800	53 fixtures per 4000 S.F.	2.15	4.85	[illegible]
0840	64 fixtures per 5000 S.F.	2.15	4.85	[illegible]
0880	Type B, 11 fixtures per 400 S.F.	4.90	8.05	[illegible]
0920	15 fixtures per 600 S.F.	4.54	7.70	[illegible]
0960	24 fixtures per 1000 S.F.	4.45	7.70	[illegible]
1000	35 fixtures per 1600 S.F.	4.16	7.30	[illegible]
1040	42 fixtures per 2000 S.F.	4.08	7.35	[illegible]
1080	61 fixtures per 3000 S.F.	4.09	7.10	[illegible]
1160	80 fixtures per 4000 S.F.	3.97	7.25	[illegible]
1200	98 fixtures per 5000 S.F.	3.96	7.20	[illegible]
1240	Type C, 11 fixtures per 400 S.F.	4.06	8.50	[illegible]
1280	14 fixtures per 600 S.F.	3.63	7.95	[illegible]
1320	23 fixtures per 1000 S.F.	3.61	7.90	[illegible]
1360	34 fixtures per 1600 S.F.	3.48	7.80	[illegible]
1400	43 fixtures per 2000 S.F.	3.51	7.70	[illegible]
1440	63 fixtures per 3000 S.F.	3.42	7.60	[illegible]
1520	81 fixtures per 4000 S.F.	3.35	7.50	[illegible]
1560	101 fixtures per 5000 S.F.	3.35	7.50	[illegible]
1600	Type D, 8 fixtures per 400 S.F.	3.66	6.60	[illegible]
1640	12 fixtures per 600 S.F.	3.66	6.55	[illegible]
1680	19 fixtures per 1000 S.F.	3.52	6.40	[illegible]
1720	27 fixtures per 1600 S.F.	3.30	6.25	[illegible]
1760	34 fixtures per 2000 S.F.	3.28	6.15	[illegible]
1800	48 fixtures per 3000 S.F.	3.15	6	[illegible]
1880	64 fixtures per 4000 S.F.	3.15	6	[illegible]
1920	79 fixtures per 5000 S.F.	3.15	6	[illegible]

RS Means Assemblies Cost Data: 2011 (Page 372)

D5020 110	Receptacle (by Wattage)		COST PER S.F.	
		MAT.	INST.	TOTAL
0190	Receptacles include plate, box, conduit, wire & transformer when required			
0200	2.5 per 1000 S.F., .3 watts per S.F.	.38	1.33	1.71
0240	With transformer	.45	1.40	1.85
0280	4 per 1000 S.F., .5 watts per S.F. RD5010 -110	.43	1.55	1.98
0320	With transformer	.53	1.65	2.18
0360	5 per 1000 S.F., .6 watts per S.F.	.51	1.83	2.34
0400	With transformer	.65	1.96	2.61
0440	8 per 1000 S.F., .9 watts per S.F.	.53	2.03	2.56
0480	With transformer	.72	2.21	2.93
0520	10 per 1000 S.F., 1.2 watts per S.F.	.58	2.20	2.78
0560	With transformer	.89	2.50	3.39
0600	16.5 per 1000 S.F., 2.0 watts per S.F.	.68	2.75	3.43
0640	With transformer	1.21	3.26	4.47
0680	20 per 1000 S.F.,2.4 watts per S.F.	.71	3	3.71
0720	With transformer	1.33	3.60	4.93

RS Means Assemblies Cost Data: 2011 (Page 357)

D5090 210	Generators (by kW)		COST PER kW	
		MAT.	INST.	TOTAL
0190	Generator sets, include battery, charger, muffler & transfer switch			
0200	Gas/gasoline operated, 3 phase, 4 wire, 277/480 volt, 7.5 kW	1,175	260	1,435
0240	11.5 kW RD5010 -110	1,075	197	1,272
0280	20 kW	730	129	859
0320	35 kW	495	84	579
0360	80 kW	355	51	406
0400	100 kW	310	49.50	359.50
0440	125 kW	510	46	556
0480	185 kW	455	35	490
0560	Diesel engine with fuel tank, 30 kW	770	97.50	867.50
0600	50 kW	550	77.50	627.50
0720	125 kW	335	45	380
0760	150 kW	320	41.50	361.50
0800	175 kW	297	36.50	333.50
0840	200 kW	268	34	302
0880	250 kW	252	28	280
0920	300 kW	228	24.50	252.50
0960	350 kW	220	23	243
1000	400 kW	239	21.50	260.50
1040	500 kW	240	18	258
1200	750 kW	263	11.30	274.30
1400	1000 kW	244	12	256

RS Means Assemblies Cost Data: 2011 (Page 392)

Plumbing

D20 Plumbing

D2090 Other Plumbing Systems

D2090 810	Piping - Installed - Unit Costs	COST PER L.F. MAT.	COST PER L.F. INST.	COST PER L.F. TOTAL
1940	1-1/2" diameter	15.30	11.85	27.15
1960	2" diameter	23.50	14.55	38.05
1980	2-1/2" diameter	35.50	18	53.50
2000	3" diameter	48	19.85	67.85
2020	4" diameter	86.50	29	115.50
2040	5" diameter	201	32	233
2060	6" diameter	283	42.50	325.50
2080	8" diameter	470	47	517
2120	Type DWV, 1-1/4" diameter	12.15	10.65	22.80
2160	1-1/2" diameter	15.05	11.85	26.90
2180	2" diameter	20	14.55	34.55
2200	3" diameter	37	19.85	56.85
2220	4" diameter	65.50	29	94.50
2240	5" diameter	183	32	215
2260	6" diameter	263	42.50	305.50
2280	8" diameter	630	47	677
2800	Plastic,PVC, DWV, schedule 40, 1-1/4" diameter	5.10	15.25	20.35
2820	1-1/2" diameter	4.98	17.80	22.78
2830	2" diameter	5.45	19.55	25
2840	3" diameter	8.25	22	30.25
2850	4" diameter	10.45	24	34.45
2890	6" diameter	17.70	29.50	47.20
3010	Pressure pipe 200 PSI, 1/2" diameter	3.68	11.85	15.53
3030	3/4" diameter	3.94	12.55	16.49
3040	1" diameter	4.94	13.90	18.84
3050	1-1/4" diameter	5.75	15.25	21
3060	1-1/2" diameter	5.85	17.80	23.65
3070	2" diameter	6.55	19.55	26.10
3080	2-1/2" diameter	10.35	20.50	30.85
3090	3" diameter	11.35	22	33.35
3100	4" diameter	16.65	24	40.65
3110	6" diameter	28.50	29.50	58
3120	8" diameter	42.50	37.50	80
4000	Steel, schedule 40, black, threaded, 1/2" diameter	4.18	10.15	14.33
4020	3/4" diameter	4.80	10.50	15.30
4030	1" diameter	6.75	12.10	18.85
4040	1-1/4" diameter	8.30	12.95	21.25
4050	1-1/2" diameter	9.60	14.40	24
4060	2" diameter	12.60	18	30.60
4070	2-1/2" diameter	19	23	42
4080	3" diameter	24	27	51
4090	4" diameter	35.50	32	67.50
4100	Grooved, 5" diameter	23.50	31	54.50
4110	6" diameter	30	42.50	72.50
4120	8" diameter	45.50	48.50	94
4130	10" diameter	67.50	58	125.50
4140	12" diameter	95	66.50	161.50
4200	Galvanized, threaded, 1/2" diameter	5.65	10.15	15.80
4220	3/4" diameter	11.30	10.50	21.80
4230	1" diameter	8.90	12.10	21
4240	1-1/4" diameter	11.15	12.95	24.10
4250	1-1/2" diameter	13	14.40	27.40
4260	2" diameter	17.15	18	35.15
4270	2-1/2" diameter	28	23	51
4280	3" diameter	35	27	62
4290	4" diameter	50.50	32	82.50
4300	Grooved, 5" diameter	50.50	31	81.50
4310	6" diameter	56.50	42.50	99

RS Means Assemblies Cost Data: 2011 (Page 299)

D2010 924	Three Fixture Bathroom, One Wall Plumbing	COST EACH		
		MAT.	INST.	TOTAL
1150	Bathroom, three fixture, one wall plumbing			
1160	Lavatory, water closet & bathtub			
1170	Stand alone	2,925	2,200	5,125
1180	Share common plumbing wall *	2,525	1,575	4,100

D2010 926	Three Fixture Bathroom, Two Wall Plumbing	COST EACH		
		MAT.	INST.	TOTAL
2130	Bathroom, three fixture, two wall plumbing			
2140	Lavatory, water closet & bathtub			
2160	Stand alone	2,950	2,225	5,175
2180	Long plumbing wall common *	2,650	1,775	4,425
3610	Lavatory, bathtub & water closet			
3620	Stand alone	3,250	2,525	5,775
3640	Long plumbing wall common *	3,000	2,300	5,300
4660	Water closet, corner bathtub & lavatory			
4680	Stand alone	4,300	2,250	6,550
4700	Long plumbing wall common *	3,875	1,700	5,575
6100	Water closet, stall shower & lavatory			
6120	Stand alone	3,075	2,525	5,600
6140	Long plumbing wall common *	2,875	2,325	5,200
7060	Lavatory, corner stall shower & water closet			
7080	Stand alone	3,375	2,225	5,600
7100	Short plumbing wall common *	2,725	1,500	4,225

RS Means Assemblies Cost Data: 2011 (Page 281)

Fire Suppression

D4010 410	Wet Pipe Sprinkler Systems		COST PER S.F.		
			MAT.	INST.	TOTAL
0520	Wet pipe sprinkler systems, steel, black, sch. 40 pipe				
0530	Light hazard, one floor, 500 S.F.		2.57	2.90	5.
0560	1000 S.F.	RD4010 -100	5.05	3.03	8.
0580	2000 S.F.		4.50	3.04	7.
0600	5000 S.F.	RD4020 -300	2.23	2.15	4.
0620	10,000 S.F.		1.55	1.83	3.
0640	50,000 S.F.		1.17	1.63	2.
0660	Each additional floor, 500 S.F.		1.34	2.47	3.

RS Means Assemblies Cost Data: 2011 (Page 344)

Detailed Assemblies Estimate Data:

Foundation

A1010 110	Strip Footings	COST PER L.F.		
		MAT.	INST.	TOTAL
2100	Strip footing, load 2.6 KLF, soil capacity 3 KSF, 16" wide x 8" deep plain	7.55	13.10	20.65
2300	Load 3.9 KLF, soil capacity, 3 KSF, 24" wide x 8" deep, plain	9.40	14.35	23.75
2500	Load 5.1KLF, soil capacity 3 KSF, 24" wide x 12" deep, reinf. RA1010 -140	14.95	22	36.95
2700	Load 11.1KLF, soil capacity 6 KSF, 24" wide x 12" deep, reinf.	14.95	22	36.95
2900	Load 6.8 KLF, soil capacity 3 KSF, 32" wide x 12" deep, reinf.	18.25	24	42.25
3100	Load 14.8 KLF, soil capacity 6 KSF, 32" wide x 12" deep, reinf.	18.25	24	42.25
3300	Load 9.3 KLF, soil capacity 3 KSF, 40" wide x 12" deep, reinf.	21.50	25.50	47
3500	Load 18.4 KLF, soil capacity 6 KSF, 40" wide x 12" deep, reinf.	21.50	26	47.50
3700	Load 10.1KLF, soil capacity 3 KSF, 48" wide x 12" deep, reinf.	24	28	52
3900	Load 22.1KLF, soil capacity 6 KSF, 48" wide x 12" deep, reinf.	25.50	29.50	55
4100	Load 11.8KLF, soil capacity 3 KSF, 56" wide x 12" deep, reinf.	28	31	59
4300	Load 25.8KLF, soil capacity 6 KSF, 56" wide x 12" deep, reinf.	30.50	33.50	64
4500	Load 10KLF, soil capacity 3 KSF, 48" wide x 16" deep, reinf.	30.50	32	62.50
4700	Load 22KLF, soil capacity 6 KSF, 48" wide, 16" deep, reinf.	31	33	64
4900	Load 11.6KLF, soil capacity 3 KSF, 56" wide x 16" deep, reinf.	34.50	46	80.50
5100	Load 25.6KLF, soil capacity 6 KSF, 56" wide x 16" deep, reinf.	36.50	48	84.50
5300	Load 13.3KLF, soil capacity 3 KSF, 64" wide x 16" deep, reinf.	40	38.50	78.50
5500	Load 29.3KLF, soil capacity 6 KSF, 64" wide x 16" deep, reinf.	42.50	41.50	84
5700	Load 15KLF, soil capacity 3 KSF, 72" wide x 20" deep, reinf.	53	46.50	99.50
5900	Load 33KLF, soil capacity 6 KSF, 72" wide x 20" deep, reinf.	56	49.50	105.50
6100	Load 18.3KLF, soil capacity 3 KSF, 88" wide x 24" deep, reinf.	75	58.50	133.50
6300	Load 40.3KLF, soil capacity 6 KSF, 88" wide x 24" deep, reinf.	81	65	146
6500	Load 20KLF, soil capacity 3 KSF, 96" wide x 24" deep, reinf.	81.50	62	143.50
6700	Load 44 KLF, soil capacity 6 KSF, 96" wide x 24" deep, reinf.	86	67	153

RS Means Assemblies Cost Data: 2011 (Page 2)

A1020 310	Caissons	COST EACH		
		MAT.	INST.	TOTAL
2200	Caisson, stable ground, 3000 PSI conc, 10 KSF brng, 200K load, 2'-0"x50'-0	885	1,850	2,735
2400	400K load, 2'-6"x50'-0"	1,475	2,950	4,425
2600	800K load, 3'-0"x100'-0" RA1020 -200	4,025	7,050	11,075
2800	1200K load, 4'-0"x100'-0"	6,900	8,875	15,775
3000	1600K load, 5'-0"x150'-0"	15,500	13,700	29,200
3200	2400K load, 6'-0"x150'-0"	22,600	17,800	40,400
3400	3200K load, 7'-0"x200'-0"	40,800	25,900	66,700
5000	Wet ground, 3000 PSI conc., 10 KSF brng, 200K load, 2'-0"x50'-0"	765	2,600	3,365
5200	400K load, 2'-6"x50'-0"	1,275	4,450	5,725
5400	800K load, 3'-0"x100'-0"	3,475	12,000	15,475
5600	1200K load, 4'-0"x100'-0"	5,975	17,800	23,775
5800	1600K load, 5'-0"x150'-0"	13,300	38,400	51,700
6000	2400K load, 6'-0"x150'-0"	19,500	47,200	66,700
6200	3200K load, 7'-0"x200'-0"	35,000	76,000	111,000
7800	Soft rock, 3000 PSI conc., 10 KSF brng, 200K load, 2'-0"x50'-0"	765	14,100	14,865
8000	400K load, 2'-6"x50'-0"	1,275	22,900	24,175
8200	800K load, 3'-0"x100'-0"	3,475	60,000	63,475
8400	1200K load, 4'-0"x100'-0"	5,975	88,500	94,475
8600	1600K load, 5'-0"x150'-0"	13,300	180,500	193,800
8800	2400K load, 6'-0"x150'-0"	19,500	214,500	234,000
9000	3200K load, 7'-0"x200'-0"	35,000	342,500	377,500

RS Means Assemblies Cost Data: 2011 (Page 22)

A1020 210	Grade Beams	COST PER L.F.		
		MAT.	INST.	TOTAL
2220	Grade beam, 15' span, 28" deep, 12" wide, 8 KLF load	32.50	48.50	81
2240	14" wide, 12 KLF load	33.50	49	82.50
2260	40" deep, 12" wide, 16 KLF load	33.50	60	93.50
2280	20 KLF load	38.50	64.50	103
2300	52" deep, 12" wide, 30 KLF load	44.50	81	125.50
2320	40 KLF load	54.50	90	144.50
2340	50 KLF load	64.50	98	162.50
3360	20' span, 28" deep, 12" wide, 2 KLF load	20.50	37.50	58
3380	16" wide, 4 KLF load	27.50	42	69.50
3400	40" deep, 12" wide, 8 KLF load	33.50	60	93.50
3420	12 KLF load	42.50	67	109.50
3440	14" wide, 16 KLF load	51.50	75	126.50
3460	52" deep, 12" wide, 20 KLF load	55.50	91	146.50
3480	14" wide, 30 KLF load	76.50	109	185.50
3500	20" wide, 40 KLF load	90	114	204
3520	24" wide, 50 KLF load	112	130	242
4540	30' span, 28" deep, 12" wide, 1 KLF load	21.50	38.50	60
4560	14" wide, 2 KLF load	34.50	53	87.50
4580	40" deep, 12" wide, 4 KLF load	41	63	104
4600	18" wide, 8 KLF load	58	77.50	135.50
4620	52" deep, 14" wide, 12 KLF load	73.50	106	179.50
4640	20" wide, 16 KLF load	90.50	115	205.50
4660	24" wide, 20 KLF load	112	131	243
4680	36" wide, 30 KLF load	161	164	325
4700	48" wide, 40 KLF load	212	200	412
5720	40' span, 40" deep, 12" wide, 1 KLF load	29.50	56	85.50

RA1020-230

RS Means Assemblies Cost Data: 2011 (Page 20)

Floor Construction

A1030 120	Plain & Reinforced		COST PER S.F.		
			MAT.	INST.	TOTAL
2220	Slab on grade, 4" thick, non industrial, non reinforced		1.99	2.47	4.46
2240	Reinforced		2.13	2.83	4.96
2260	Light industrial, non reinforced	RA1030 -200	2.59	3.03	5.62
2280	Reinforced		2.73	3.39	6.12
2300	Industrial, non reinforced		3.22	6.35	9.57
2320	Reinforced		3.36	6.70	10.06
3340	5" thick, non industrial, non reinforced		2.32	2.54	4.86
3360	Reinforced		2.46	2.90	5.36
3380	Light industrial, non reinforced		2.93	3.10	6.03
3400	Reinforced		3.07	3.46	6.53
3420	Heavy industrial, non reinforced		4.19	7.55	11.74
3440	Reinforced		4.31	7.95	12.26
4460	6" thick, non industrial, non reinforced		2.76	2.49	5.25
4480	Reinforced		3.01	2.97	5.98
4500	Light industrial, non reinforced		3.38	3.05	6.43
4520	Reinforced		3.78	3.69	7.47
4540	Heavy industrial, non reinforced		4.65	7.65	12.30
4560	Reinforced		4.90	8.15	13.05
5580	7" thick, non industrial, non reinforced		3.10	2.58	5.68
5600	Reinforced		3.38	3.09	6.47
5620	Light industrial, non reinforced		3.73	3.14	6.87
5640	Reinforced		4.01	3.65	7.66
5660	Heavy industrial, non reinforced		5	7.55	12.55
5680	Reinforced		5.25	8.05	13.30

RS Means Assemblies Cost Data: 2011 (Page 24)

B1010 230	Precast Plank with 2" Concrete Topping							
	SPAN (FT.)	SUPERIMPOSED LOAD (P.S.F.)	TOTAL DEPTH (IN.)	DEAD LOAD (P.S.F.)	TOTAL LOAD (P.S.F.)	COST PER S.F.		
						MAT.	INST.	TOTAL
2000	10	40	6	75	115	7	5.50	12.50
2100		75	8	75	150	8.05	5.05	13.10
2200		100	8	75	175	8.05	5.05	13.10
2500	15	40	8	75	115	8.05	5.05	13.10
2600		75	8	75	150	8.05	5.05	13.10
2700		100	8	75	175	8.05	5.05	13.10
2800	20	40	8	75	115	8.05	5.05	13.10
2900		75	8	75	150	8.05	5.05	13.10
3000		100	8	75	175	8.05	5.05	13.10
3100	25	40	8	75	115	8.05	5.05	13.10
3200		75	8	75	150	8.05	5.05	13.10
3300		100	10	80	180	8.80	4.68	13.48
3400	30	40	10	80	120	8.80	4.68	13.48
3500		75	10	80	155	8.80	4.68	13.48
3600		100	10	80	180	8.80	4.68	13.48
3700	35	40	12	95	135	9.15	4.40	13.55
3800		75	12	95	170	9.15	4.40	13.55
3900		100	14	95	195	9.70	4.18	13.88
4000	40	40	12	95	135	9.15	4.40	13.55
4500		75	14	95	170	9.70	4.18	13.88
5000	45	40	14	95	135	9.70	4.18	13.88

RS Means Assemblies Cost Data: 2011 (Page 70)

A20 Basement Construction

A2020 Basement Walls

A2020 110 Walls, Cast in Place

	WALL HEIGHT (FT.)	PLACING METHOD	CONCRETE (C.Y. per L.F.)	REINFORCING (LBS. per L.F.)	WALL THICKNESS (IN.)	COST PER L.F. MAT.	INST.	TOTAL
3200	6'	pumped	.111	4.95	6	22	74	96
3220			.149	7.20	8	27	77	104
3240			.184	9.00	10	32	78.50	110.50
3260			.222	10.8	12	37	81	118
3280			.260	12.15	14	41.50	82	123.50
3300			.300	14.39	16	47	84.50	131.50
5000	8'	direct chute	.148	6.6	6	29.50	96.50	126
5020			.199	9.6	8	36.50	99.50	136
5040			.250	12	10	43	101	144
5060			.296	14.39	12	49	103	152
5080			.347	16.19	14	51	104	155
5100			.394	19.19	16	62	108	170
5200	8'	pumped	.148	6.6	6	29.50	99	128.50
5220			.199	9.6	8	36.50	103	139.50
5240			.250	12	10	43	105	148
5260			.296	14.39	12	49	107	156
5280			.347	16.19	14	51	108	159
5300			.394	19.19	16	62	113	175
6020	10'	direct chute	.248	12	8	45.50	124	169.50
6040			.307	14.99	10	53	126	179
6060			.370	17.99	12	61.50	129	190.50
6080			.433	20.24	14	69.50	131	200.50
6100			.493	23.99	16	77.50	135	212.50
6220	10'	pumped	.248	12	8	45.50	128	173.50
6240			.307	14.99	10	53	130	183
6260			.370	17.99	12	61.50	135	196.50
6280			.433	20.24	14	69.50	137	206.50
6300			.493	23.99	16	77.50	141	218.50
7220	12'	pumped	.298	14.39	8	54.50	154	208.50
7240			.369	17.99	10	64	157	221
7260			.444	21.59	12	73.50	162	235.50
7280			.52	24.29	14	83	164	247
7300			.591	28.79	16	93	168	261
7420	12'	crane & bucket	.298	14.39	8	54.50	160	214.50
7440			.369	17.99	10	64	165	229
7460			.444	21.59	12	73.50	171	244.50
7480			.52	24.29	14	83	175	258
7500			.591	28.79	16	93	182	275

RS Means Assemblies Cost Data: 2011 (Page 29)

Bearing Walls

B2010 111 — Reinforced Concrete Block Wall - Regular Weight

	TYPE	SIZE (IN.)	STRENGTH (P.S.I.)	VERT. REINF & GROUT SPACING	COST PER S.F. MAT.	INST.	TOTAL
5400	Hollow	8x8x16	2,000	#4 @ 48"	3.11	7.25	10.36
5430				#5 @ 32"	3.33	7.65	10.98
5440				#5 @ 16"	3.84	8.75	12.59
5450		8x8x16	4,500	#4 @ 48"	3.63	7.35	10.98
5480				#5 @ 32"	3.86	7.65	11.51
5490				#5 @ 16"	4.37	8.75	13.12
5500		12x8x16	2,000	#4 @ 48"	4.38	9.35	13.73
5530				#5 @ 32"	4.67	9.65	14.32
5540				#5 @ 16"	5.40	10.80	16.20
5550			4,500	#4 @ 48"	4.90	9.35	14.25
5580				#5 @ 32"	5.20	9.65	14.85
5590				#5 @ 16"	5.90	10.80	16.70
6100	75% solid	6x8x16	2,000	#4 @ 48"	3.13	6.80	9.93
6130				#5 @ 32"	3.28	7	10.28
6140				#5 @ 16"	3.55	7.75	11.30
6150			4,500	#4 @ 48"	3.49	6.80	10.29
6180				#5 @ 32"	3.64	7	10.64
6190				#5 @ 16"	3.91	7.75	11.66
6200		8x8x16	2,000	#4 @ 48"	3.52	7.30	10.82
6230				#5 @ 32"	3.68	7.55	11.23
6240				#5 @ 16"	3.97	8.45	12.42
6250			4,500	#4 @ 48"	4.23	7.30	11.53
6280				#5 @ 32"	4.39	7.55	11.94
6290				#5 @ 16"	4.68	8.45	13.13
6300		12x8x16	2,000	#4 @ 48"	5.05	9.35	14.40
6330				#5 @ 32"	5.25	9.60	14.85
6340				#5 @ 16"	5.65	10.50	16.15
6350			4,500	#4 @ 48"	5.70	9.35	15.05
6380				#4 @ 32"	5.95	9.60	15.55
6390				#5 @ 16"	6.35	10.50	16.85
6500	Solid-double Wythe	2-4x8x16	2,000	#4 @ 48" E.W.	5.20	13.45	18.65
6530				#5 @ 16" E.W.	5.90	14.30	20.20
6550			4,500	#4 @ 48" E.W.	7	13.35	20.35
6580				#5 @ 16" E.W.	7.70	14.20	21.90
6600		2-6x8x16	2,000	#4 @ 48" E.W.	5.95	14.40	20.35
6630				#5 @ 16" E.W.	6.60	15.25	21.85
6650			4,000	#4 @ 48" E.W.	8.35	14.30	22.65
6680				#5 @ 16" E.W.	9.05	15.15	24.20

RS Means Assemblies Cost Data: 2011 (Page 134)

Roofing System

B1020 102	Wood/Flat or Pitched	COST PER S.F.		
		MAT.	INST.	TOTAL
2500	Flat rafter, 2"x4", 12" O.C.	1.03	1.62	2.65
2550	16" O.C.	.93	1.39	2.32
2600	24" O.C.	.75	1.19	1.94
2900	2"x6", 12" O.C.	1.27	1.62	2.89
2950	16" O.C.	1.11	1.39	2.50
3000	24" O.C.	.87	1.18	2.05
3300	2"x8", 12" O.C.	1.51	1.75	3.26
3350	16" O.C.	1.29	1.49	2.78
3400	24" O.C.	.99	1.26	2.25
3700	2"x10", 12" O.C.	1.98	2	3.98
3750	16" O.C.	1.64	1.67	3.31
3800	24" O.C.	1.22	1.37	2.59
4100	2"x12", 12" O.C.	2.28	2.02	4.30
4150	16" O.C.	1.87	1.69	3.56
4200	24" O.C.	1.38	1.39	2.77
4500	2"x14", 12" O.C.	2.68	2.94	5.62
4550	16" O.C.	2.17	2.39	4.56
4600	24" O.C.	1.58	1.86	3.44
4900	3"x6", 12" O.C.	2.53	1.71	4.24
4950	16" O.C.	2.06	1.46	3.52
5000	24" O.C.	1.50	1.23	2.73
5300	3"x8", 12" O.C.	3.22	1.91	5.13
5350	16" O.C.	2.57	1.61	4.18
5400	24" O.C.	1.84	1.33	3.17
5700	3"x10", 12" O.C.	3.86	2.18	6.04
5750	16" O.C.	3.06	1.81	4.87
5800	24" O.C.	2.17	1.47	3.64
6100	3"x12", 12" O.C.	4.59	2.62	7.21
6150	16" O.C.	3.61	2.14	5.75
6200	24" O.C.	2.53	1.69	4.22

RS Means Assemblies Cost Data: 2011 (Page 106)

Value Engineering Data:

04 22 10.23 Concrete Block, Decorative

0010	**CONCRETE BLOCK, DECORATIVE**, C90, 2000 psi									
0020	Embossed, simulated brick face									
0100	8" x 16" units, 4" thick	D-8	400	.100	S.F.	3.51	3.98			7.49
0200	8" thick		340	.118		4.83	4.68			9.51
0250	12" thick		300	.133		6.35	5.30			11.65
0400	Embossed both sides									
0500	8" thick	D-8	300	.133	S.F.	5.40	5.30			10.70
0550	12" thick	"	275	.145	"	6.85	5.80			12.65
1000	Fluted high strength									
1100	8" x 16" x 4" thick, flutes 1 side,	D-8	345	.116	S.F.	4.17	4.62			8.79
1150	Flutes 2 sides		335	.119		5.05	4.75			9.80
1200	8" thick		300	.133		6.60	5.30			11.90
1250	For special colors, add					.41				.41
1400	Deep grooved, smooth face									
1450	8" x 16" x 4" thick	D-8	345	.116	S.F.	2.72	4.62			7.34
1500	8" thick	"	300	.133	"	4.68	5.30			9.98

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07 21 29 – Sprayed Insulation

07 21 29.10 Sprayed-On Insulation

0010	**SPRAYED-ON INSULATION**										
0020	Fibrous/cementitious, finished wall, 1" thick, R3.7	G	G-2	2050	.012	S.F.	.24	.42	.06	.72	1.01
0100	Attic, 5.2" thick, R19	G		1550	.015	"	.42	.56	.08	1.06	1.45
0200	Fiberglass, R4 per inch, vertical	G		2050	.012	B.F.	.15	.42	.06	.63	.92
0210	Horizontal	G		1550	.015	"	.15	.56	.08	.79	1.16
0300	Closed cell, spray polyurethane foam, 2 pounds per cubic foot density										
0310	1" thick	G	G-2A	6000	.004	S.F.	.41	.13	.10	.64	.78
0320	2" thick	G		3000	.008		.82	.26	.20	1.28	1.57
0330	3" thick	G		2000	.012		1.23	.39	.30	1.92	2.36
0335	3-1/2" thick	G		1715	.014		1.44	.46	.35	2.25	2.75
0340	4" thick	G		1500	.016		1.64	.52	.40	2.56	3.14
0350	5" thick	G		1200	.020		2.05	.65	.49	3.19	3.92
0355	5-1/2" thick	G		1090	.022		2.26	.72	.54	3.52	4.32
0360	6" thick	G		1000	.024		2.46	.78	.59	3.83	4.71
9000	Minimum labor/equipment charge		G-2	2	12	Job		435	63	498	765

- RS Means Facilities Construction Cost Data 2011 (Page 223)

09 91 13.90 Walls, Masonry (CMU), Exterior

0350	**WALLS, MASONRY (CMU), EXTERIOR**									
0360	Concrete masonry units (CMU), smooth surface									
0370	Brushwork, latex, first coat	1 Pord	640	.013	S.F.	.06	.47			.53
0380	Second coat		960	.008		.05	.31			.36
0390	Waterproof sealer, first coat		736	.011		.25	.41			.66
0400	Second coat		1104	.007		.25	.27			.52
0410	Roll, latex, paint, first coat		1465	.005		.07	.21			.28
0420	Second coat		1790	.004		.05	.17			.22
0430	Waterproof sealer, first coat		1680	.005		.25	.18			.43
0440	Second coat		2060	.004		.25	.15			.40
0450	Spray, latex, paint, first coat		1950	.004		.05	.15			.20
0460	Second coat		2600	.003		.04	.12			.16
0470	Waterproof sealer, first coat		2245	.004		.25	.13			.38
0480	Second coat		2990	.003		.25	.10			.35

- RS Means Facilities Construction Cost Data 2011 (Page 356)

Appendix C

General Conditions Summary

(**Table 16:** General Conditions Cost)

GENERAL CONDITIONS	Cost ($)
Permits & Fees	34,160
Field Engineer	83,136
Supervision	166,272
Misc. Labor	46,080
Travel	72,096
Misc. Materials & Shipping	61,000
Testing & Surveying	106,000
Field Office	17,760
Temporary Toilet	9,600
Temporary Utilities	70,400
Security & Safety	5,800
Storage Trailers	12,000
Trash Removal	48,000
Snow Removal	8,000
Final Cleanup	31,896
Equipment Rental	1,800
TOTAL	**774,000**

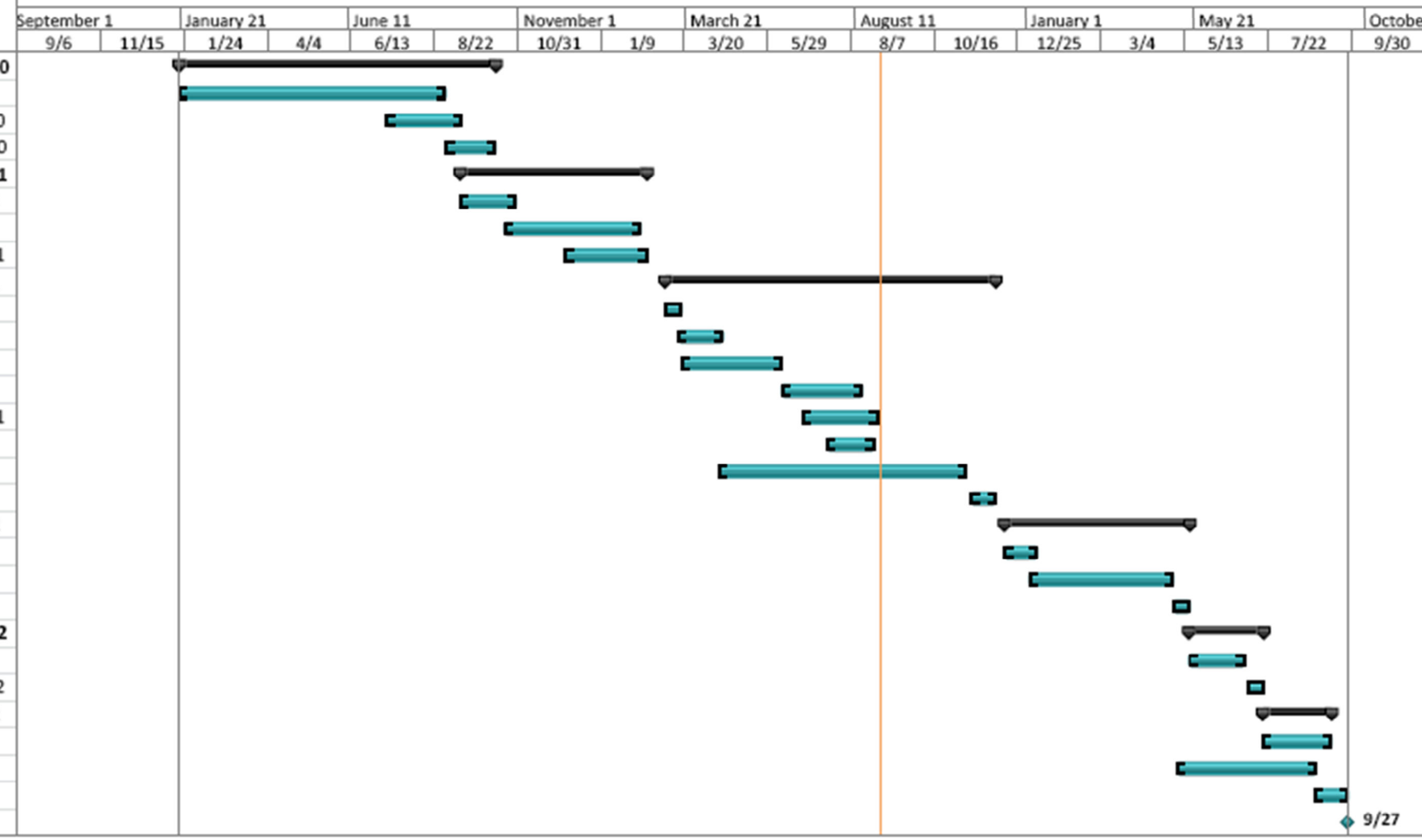
(**Table 17:** Fees & Contingency)

Fees & Contingency	Cost ($)
Pre-Construction Fee	151,000
Construction Fee	453,000
Construction Contingency	2,094,846
TOTAL	**2,698,846**

Appendix D
Project Schedules

Project Schedule Summary:

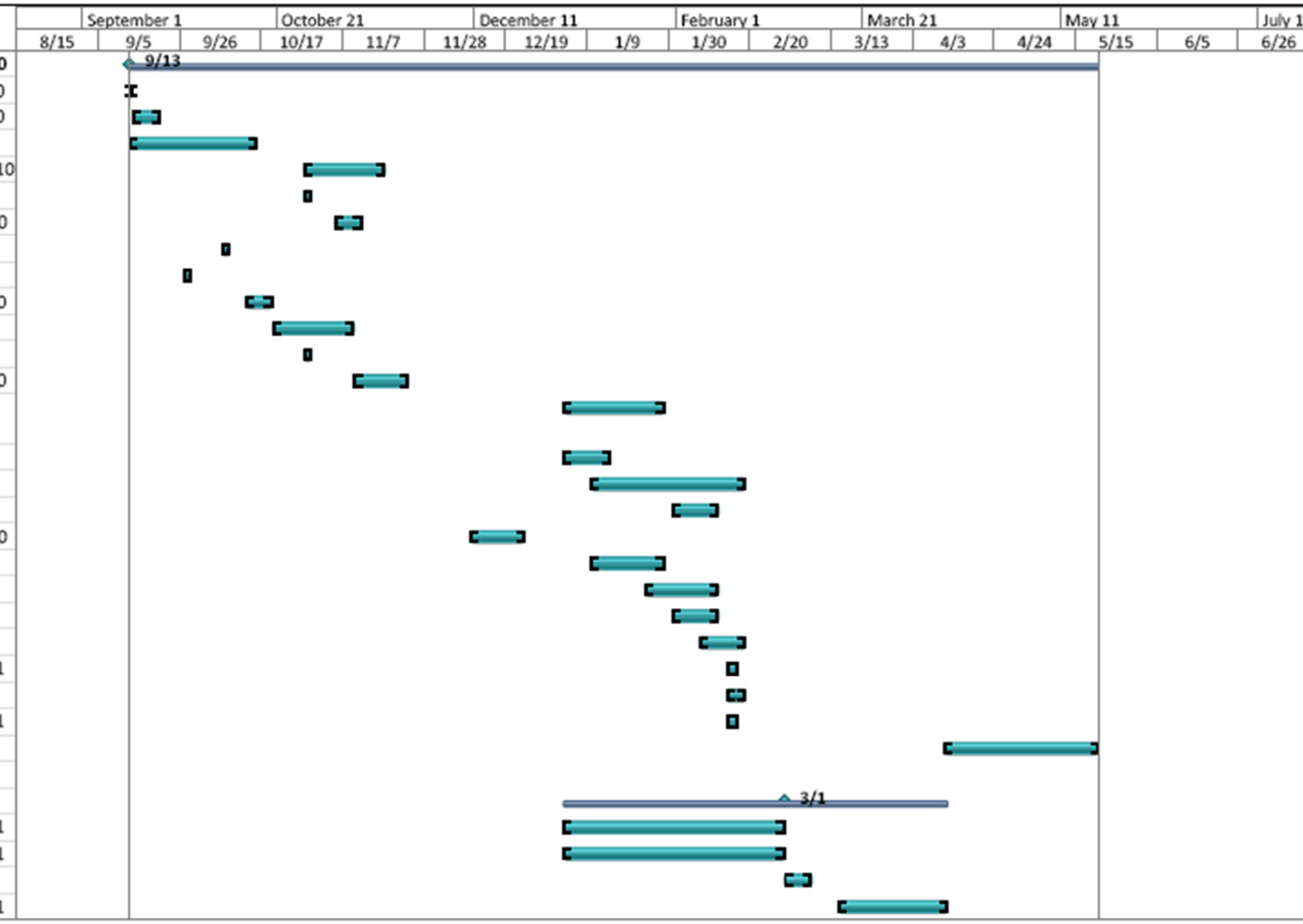
ID	Task Mode	Task Name	Duration	Start	Finish
1		**Preconstruction/Procurement**	**190 days**	**Wed 1/20/10**	**Tue 10/12/10**
2		Construction Documents	160 days	Wed 1/20/10	Tue 8/31/10
3		Permits	45 days	Tue 7/13/10	Mon 9/13/10
4		Submittals and Procurement	30 days	Wed 9/1/10	Tue 10/12/10
5		**Phase 1 & Foundations**	**113 days**	**Mon 9/13/10**	**Wed 2/16/11**
6		Preliminary Site Work	35 days	Mon 9/13/10	Fri 10/29/10
7		Building B Foundation	83 days	Wed 10/20/10	Fri 2/11/11
8		Building A Foundation	49 days	Fri 12/10/10	Wed 2/16/11
9		**Phase 2 Additions**	**198 days**	**Fri 3/4/11**	**Tue 12/6/11**
10		Slab on Grade	10 days	Fri 3/4/11	Thu 3/17/11
11		Precast Concrete Planks	28 days	Tue 3/15/11	Thu 4/21/11
12		CMU Walls	60 days	Fri 3/18/11	Thu 6/9/11
13		Roof Framing & Covering	48 days	Fri 6/10/11	Tue 8/16/11
14		Brick Casing & Sidings	45 days	Tue 6/28/11	Mon 8/29/11
15		Windows & Exterior Doors	30 days	Mon 7/18/11	Fri 8/26/11
16		MEP Installation	150 days	Mon 4/18/11	Fri 11/11/11
17		Owner Move-in of Phase 2	15 days	Wed 11/16/11	Tue 12/6/11
18		**Phase 3**	**112 days**	**Wed 12/14/11**	**Thu 5/17/12**
19		Demolish Existing Areas	20 days	Wed 12/14/11	Tue 1/10/12
20		Interior Renovations	87 days	Wed 1/4/12	Thu 5/3/12
21		Owner Move-in of Phase 3	10 days	Fri 5/4/12	Thu 5/17/12
22		**Phase 4**	**45 days**	**Thu 5/17/12**	**Wed 7/18/12**
23		Interior Renovations	33 days	Thu 5/17/12	Mon 7/2/12
24		Owner Move-in of Phase 4	10 days	Thu 7/5/12	Wed 7/18/12
25		**Phase 5**	**42 days**	**Wed 7/18/12**	**Thu 9/13/12**
26		Interior Renovations	42 days	Wed 7/18/12	Thu 9/13/12
27		Final Site Grading	85 days	Mon 5/7/12	Fri 8/31/12
28		Punch List & Close Out	20 days	Fri 8/31/12	Thu 9/27/12
29		Owner Occupancy	0 days	Thu 9/27/12	Thu 9/27/12



Project: schedule summary
Date: Thu 9/1/11

Detailed Project Schedule:

Notes	Task Name	Duration	Start	Finish
1	**Phase 1 and Foundations**	**0 days**	**Mon 9/13/10**	**Mon 9/13/10**
2	Contract	1 day	Mon 9/13/10	Mon 9/13/10
3	Establish Access Road	5 days	Tue 9/14/10	Mon 9/20/10
4	DOH Permit	25 days	Mon 9/13/10	Fri 10/15/10
5	Relocate Existing Shower Rooms	15 days	Thu 10/28/10	Wed 11/17/10
6	Build Partition at Door	2 days	Thu 10/28/10	Fri 10/29/10
7	Demolition of Existing Building/Site	5 days	Fri 11/5/10	Thu 11/11/10
8	Preliminary Building Layout	2 days	Thu 10/7/10	Fri 10/8/10
9	E & S Control (by CM)	2 days	Mon 9/27/10	Tue 9/28/10
10	Clear & Grub	5 days	Wed 10/13/10	Tue 10/19/10
11	Grade for Building B	15 days	Wed 10/20/10	Tue 11/9/10
12	Layout Building	2 days	Thu 10/28/10	Fri 10/29/10
13	Caissons	10 days	Wed 11/10/10	Tue 11/23/10
14	Excavate/Pour Caisson Caps & Grade Beams	20 days	Mon 1/3/11	Fri 1/28/11
15	Footings Building B	10 days	Mon 1/3/11	Fri 1/14/11
16	Ivany Wall Building B	30 days	Mon 1/10/11	Fri 2/18/11
17	CMU Foundations Building B	10 days	Mon 1/31/11	Fri 2/11/11
18	Rough Grade Building A	10 days	Fri 12/10/10	Thu 12/23/10
19	Excavate/Pour Footings Building A	15 days	Mon 1/10/11	Fri 1/28/11
20	Concrete Walls Building A	15 days	Mon 1/24/11	Fri 2/11/11
21	Masonry Foundations Building A	10 days	Mon 1/31/11	Fri 2/11/11
22	Backfill Building B/Ivany Wall	10 days	Mon 2/7/11	Fri 2/18/11
23	Waterproof Building A	3 days	Mon 2/14/11	Wed 2/16/11
24	Subbase for Slabs	5 days	Mon 2/14/11	Fri 2/18/11
25	Foundation Drain/Backfill Building A	3 days	Mon 2/14/11	Wed 2/16/11
26	Temporary Resident Rooms	30 days	Mon 4/11/11	Fri 5/20/11
27				
28	**Pase 2 Additions**	**0 days**	**Tue 3/1/11**	**Tue 3/1/11**
29	Shop Drawings/ Submittals/ Clearances	41 days	Mon 1/3/11	Mon 2/28/11
30	Precast Plank Drawings & Fabrication	41 days	Mon 1/3/11	Mon 2/28/11
31	Mobilize	5 days	Tue 3/1/11	Mon 3/7/11
32	Mockups	20 days	Tue 3/15/11	Mon 4/11/11



Project: Project1
Date: Mon 10/3/11

Task | Split | Milestone | Summary | Project Summary | External Tasks | External Milestone | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | Deadline | Progress

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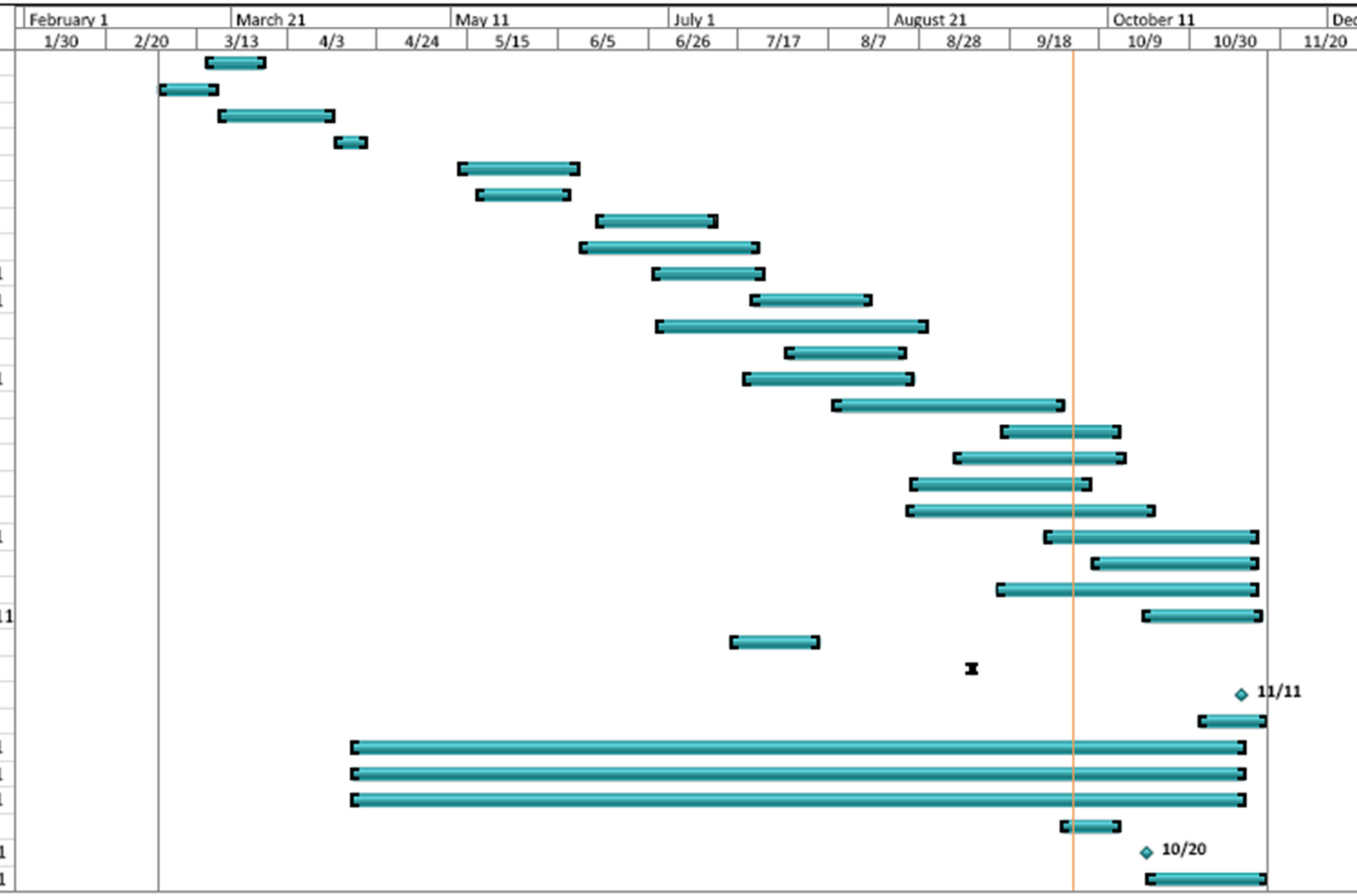
Notes	Task Name	Duration	Start
33	1st Floor Precast Plank	10 days	Tue 3/15/11
34	Concrete Slab on Grade	10 days	Fri 3/4/11
35	2nd Floor CMU Walls	19 days	Fri 3/18/11
36	3rd Floor Precast Plank	5.88 days	Thu 4/14/11
37	3rd Floor CMU Walls	20 days	Fri 5/13/11
38	Elevator Rough In	16 days	Tue 5/17/11
39	Steel Stair Framing	20 days	Tue 6/14/11
40	Roof Framing, Sheathing, & Finish	30 days	Fri 6/10/11
41	EPDM Roofing	20 days	Mon 6/27/11
42	Soffit, Fascia, Gutters	20 days	Wed 7/20/11
43	Brick Casing	45 days	Tue 6/28/11
44	Vinyl Siding	20 days	Thu 7/28/11
45	Windows & Exterior Doors	30 days	Mon 7/18/11
46	GWB/Wall Assemblies	40 days	Mon 8/8/11
47	Wall Finishes	20 days	Fri 9/16/11
48	Doors, Frames, & Hardware	30 days	Mon 9/5/11
49	Ceilings	30 days	Fri 8/26/11
50	Painting	42 days	Thu 8/25/11
51	Floor Finishes	36 days	Mon 9/26/11
52	Casework & Millwork	27 days	Fri 10/7/11
53	Ceramic Tile	43 days	Thu 9/15/11
54	Elevator Installation	20 days	Wed 10/19/11
55	Food Service Ventilators	15 days	Fri 7/15/11
56	Food Service Verification	1 day	Fri 9/9/11
57	Food Service Inspection Allegheny County Health	0 days	Fri 11/11/11
58	Food Service Demonstration, Testing, & Punch List	12 days	Tue 11/1/11
59	Plumbing	150 days	Mon 4/18/11
60	HVAC	150 days	Mon 4/18/11
61	Electrical	150 days	Mon 4/18/11
62	Comcast & Verizon Systems	10 days	Fri 9/30/11
63	Phase 2 Substantial Completion	0 days	Thu 10/20/11
61	Punch List	20 days	Thu 10/20/11



Project: Project1
Date: Mon 10/3/11

Task | Split | Milestone | Summary | Project Summary | External Tasks | External Milestone | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | Deadline | Progress

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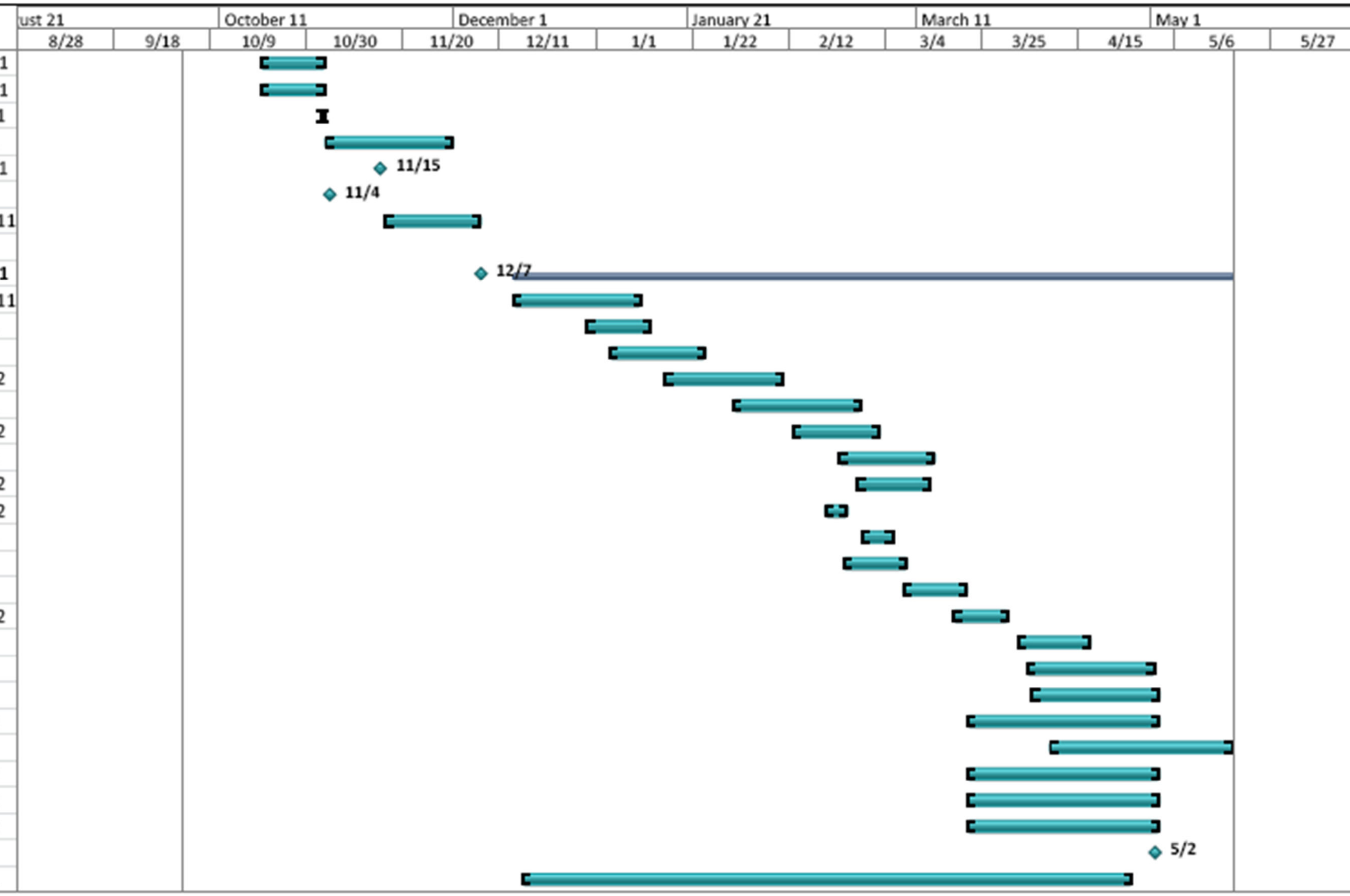
Notes	Task Name	Duration	Start
65	MVS Furniture	10 days	Thu 10/20/11
66	MVS IT & Communications	10 days	Thu 10/20/11
67	DOH Inspection - Life Safety	1 day	Wed 11/2/11
68	DOH Inspection - Nursing Division	20 days	Thu 11/3/11
69	Phase 2 Complete	0 days	Tue 11/15/11
70	MVS Laying of Cornerstone	0 days	Fri 11/4/11
71	Owner Move into new Phase 2 Additions	15 days	Wed 11/16/11
72			
73	**Phase 3**	**0 days**	**Wed 12/7/11**
74	Demolition of Existing Areas	20 days	Wed 12/14/11
75	Unit Masonry/Concrete Patching	10 days	Fri 12/30/11
76	Interior Framing	15 days	Wed 1/4/12
77	GWB Renovation Areas	20 days	Mon 1/16/12
78	Wall Finishes Renovation Areas	20 days	Tue 1/31/12
79	Ceiling Renovation Areas	15 days	Mon 2/13/12
80	Floor Finishes Renovation Areas	15 days	Thu 2/23/12
81	Doors, Frames, & Hardware Renovation Areas	12 days	Mon 2/27/12
82	2nd Floor Concrete Slab on Grade	5 days	Mon 2/20/12
83	MVS Room Modifications	5 days	Tue 2/28/12
84	2nd Floor CMU Walls	10 days	Fri 2/24/12
85	3rd Floor Precast Plank & Topping	10 days	Thu 3/8/12
86	3rd Floor CMU Walls	10 days	Mon 3/19/12
87	Phase 3 Roof Framing, Sheathing, & Finish	12 days	Mon 4/2/12
88	GWB/Wall Assemblies - Addition	20 days	Wed 4/4/12
89	Floor, Wall, & Ceiling - Addition	20 days	Thu 4/5/12
90	Painting	30 days	Thu 3/22/12
91	EIFS & Exterior Finishes	30 days	Mon 4/9/12
92	Ceramic Tile	30 days	Thu 3/22/12
93	Casework & Millwork	30 days	Thu 3/22/12
94	Food Service Equipment	30 days	Thu 3/22/12
95	Food Service Inspection Allegheny County Health	0 days	Wed 5/2/12
96	Plumbing	95 days	Fri 12/16/11



Project: Project1 Date: Mon 10/3/11	Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Deadline
	Split		External Tasks		Inactive Summary		Manual Summary		Progress
	Milestone		External Milestone		Manual Task		Start-only		
	Summary		Inactive Task		Duration-only		Finish-only		

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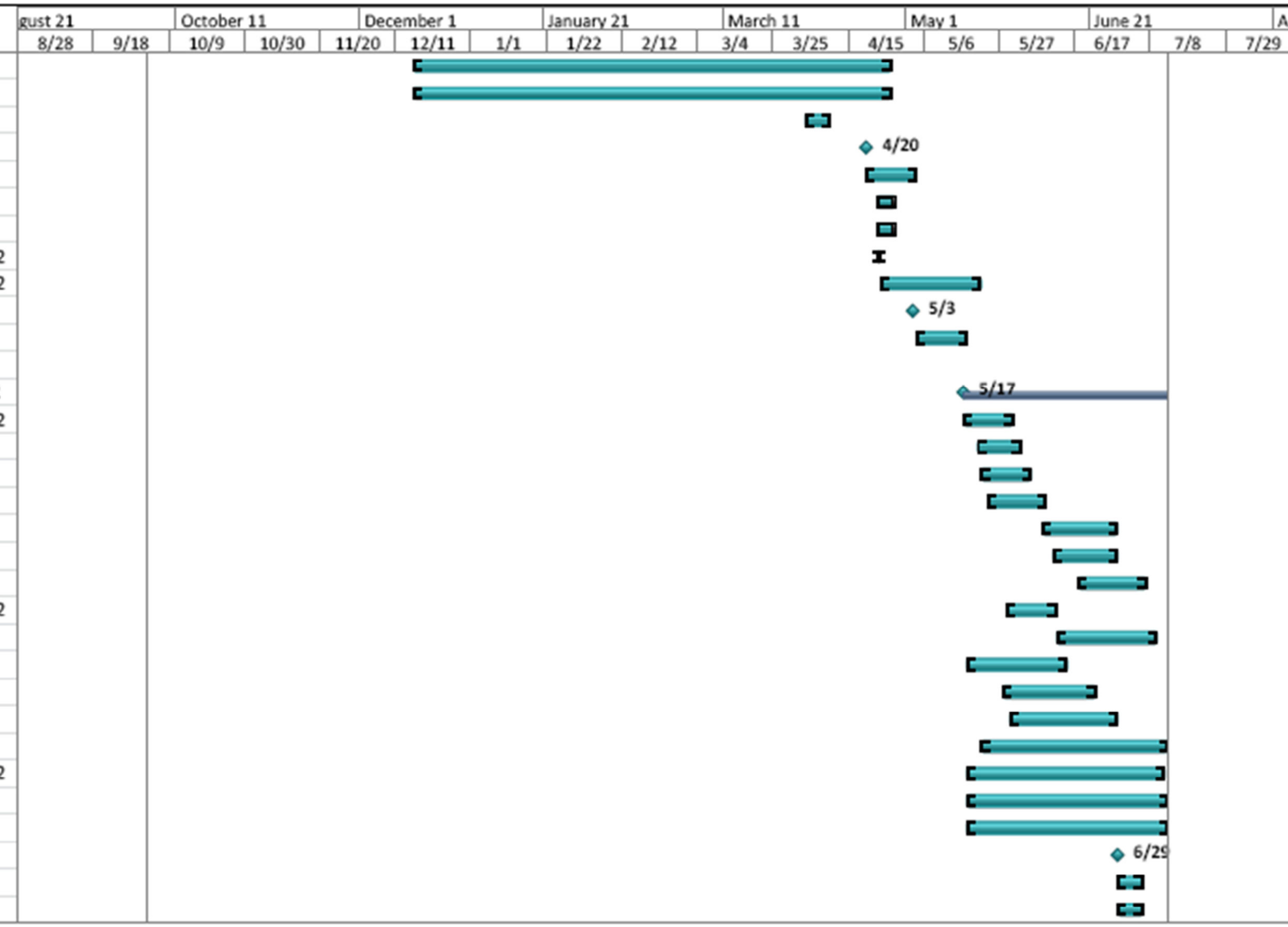
Notes	Task Name	Duration	Start	Finish
97	HVAC	95 days	Fri 12/16/11	Thu 4/26/12
98	Electrical	95 days	Fri 12/16/11	Thu 4/26/12
99	Comcast & Verizon Systems	5 days	Tue 4/3/12	Mon 4/9/12
100	Phase 3 Substantial Completion	0 days	Fri 4/20/12	Fri 4/20/12
101	Phase 3 Punch List	10 days	Fri 4/20/12	Thu 5/3/12
102	MVS Furniture	5 days	Mon 4/23/12	Fri 4/27/12
103	MVS IT & Communications	5 days	Mon 4/23/12	Fri 4/27/12
104	DOH Inspection - Life Safety	1 day	Mon 4/23/12	Mon 4/23/12
105	DOH Inspection - Nursing Division	20 days	Tue 4/24/12	Mon 5/21/12
106	Phase 3 Complete	0 days	Thu 5/3/12	Thu 5/3/12
107	Owner Move into Phase 3 Areas	10 days	Fri 5/4/12	Thu 5/17/12
108				
109	**Phase 4**	**0 days**	**Thu 5/17/12**	**Thu 5/17/12**
110	Demolition of Existing Areas	10 days	Thu 5/17/12	Wed 5/30/12
111	Unit Masonry/Concrete Patching	10 days	Mon 5/21/12	Fri 6/1/12
112	Interior Framing	10 days	Tue 5/22/12	Mon 6/4/12
113	GWB - Wall Assemblies & Patching	12 days	Thu 5/24/12	Fri 6/8/12
114	Wall Finishes	15 days	Fri 6/8/12	Thu 6/28/12
115	Ceilings	14 days	Mon 6/11/12	Thu 6/28/12
116	Floor Finishes	15 days	Mon 6/18/12	Fri 7/6/12
117	Doors, Frames, & Hardware	10 days	Tue 5/29/12	Mon 6/11/12
118	Painting	20 days	Tue 6/12/12	Mon 7/9/12
119	EIFS & Exterior Finishes	20 days	Fri 5/18/12	Thu 6/14/12
120	Ceramic Tile	20 days	Mon 5/28/12	Fri 6/22/12
121	Casework & Millwork	22 days	Wed 5/30/12	Thu 6/28/12
122	Elevators	38 days	Tue 5/22/12	Thu 7/12/12
123	Plumbing	39 days	Fri 5/18/12	Wed 7/11/12
124	HVAC	40 days	Fri 5/18/12	Thu 7/12/12
125	Electrical	40 days	Fri 5/18/12	Thu 7/12/12
126	Phase 4 Substantial Completion	0 days	Fri 6/29/12	Fri 6/29/12
127	Punch List	5 days	Fri 6/29/12	Thu 7/5/12
128	MVS Furniture	5 days	Fri 6/29/12	Thu 7/5/12



Project: Project1
Date: Mon 10/3/11

Task
Split
Milestone
Summary
Project Summary
External Tasks
External Milestone
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Deadline
Progress

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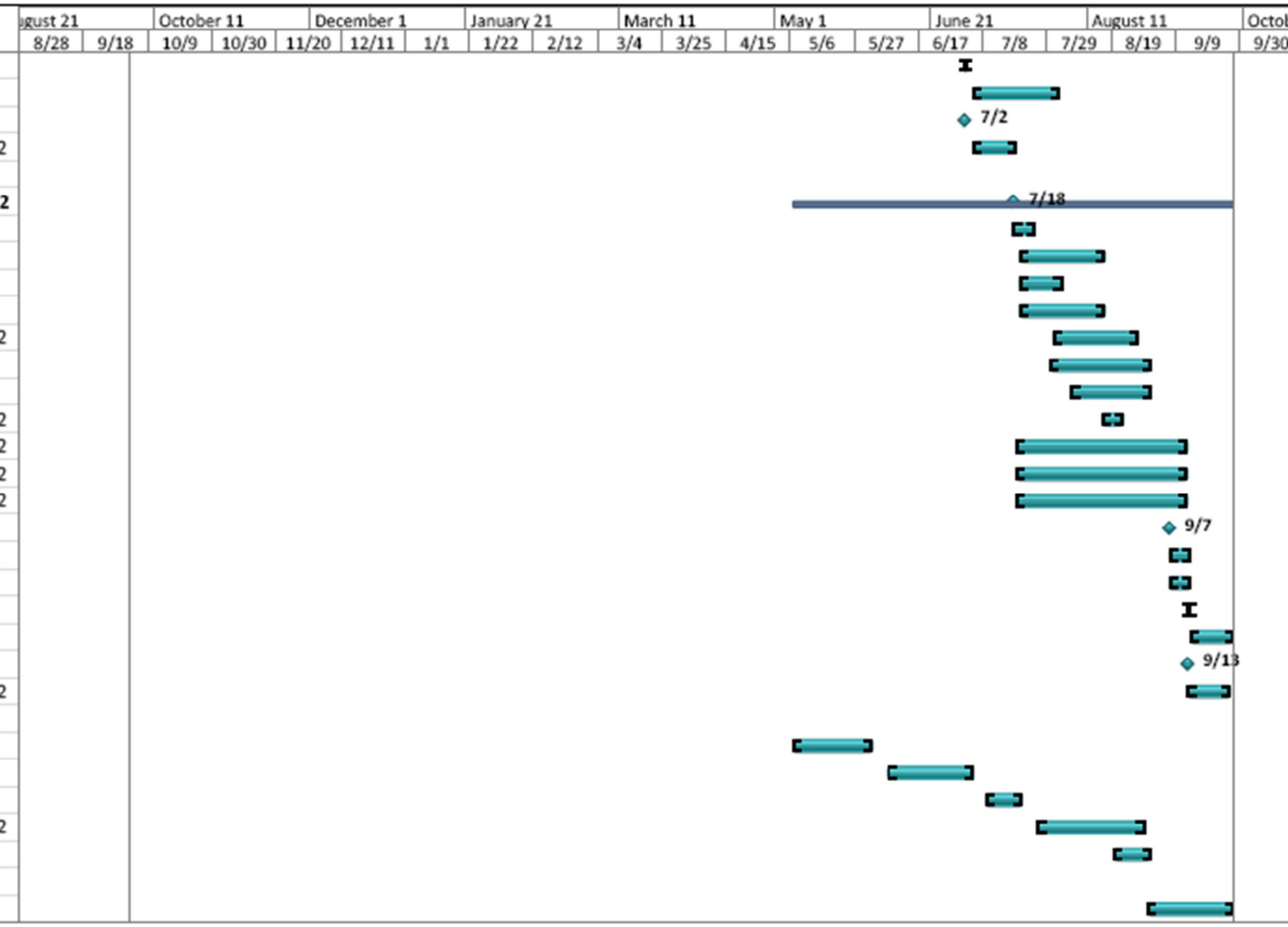
Notes	Task Name	Duration	Start	Finish
129	DOH Inspection - Life Safety	1 day	Mon 7/2/12	Mon 7/2/12
130	DOH Inspection - Nursing Division	20 days	Thu 7/5/12	Wed 8/1/12
131	Phase 4 Complete	0 days	Mon 7/2/12	Mon 7/2/12
132	Owner Move into Phase 4 Areas	10 days	Thu 7/5/12	Wed 7/18/12
133				
134	**Phase 5**	**0 days**	**Wed 7/18/12**	**Wed 7/18/12**
135	Demolition of Existing Areas	5 days	Wed 7/18/12	Tue 7/24/12
136	GWB & Patching	20 days	Fri 7/20/12	Thu 8/16/12
137	Doors, Frames, & Hardware	10 days	Fri 7/20/12	Thu 8/2/12
138	Ceilings	20 days	Fri 7/20/12	Thu 8/16/12
139	Floor Finishes	20 days	Tue 7/31/12	Mon 8/27/12
140	Painting	25 days	Mon 7/30/12	Fri 8/31/12
141	Casework & Millwork	20 days	Mon 8/6/12	Fri 8/31/12
142	Facility Chutes	5 days	Thu 8/16/12	Wed 8/22/12
143	Plumbing	40 days	Thu 7/19/12	Wed 9/12/12
144	HVAC	40 days	Thu 7/19/12	Wed 9/12/12
145	Electrical	40 days	Thu 7/19/12	Wed 9/12/12
146	Phase 5 Substantial Completion	0 days	Fri 9/7/12	Fri 9/7/12
147	Punch List	5 days	Fri 9/7/12	Thu 9/13/12
148	MVS Furniture	5 days	Fri 9/7/12	Thu 9/13/12
149	DOH Inspection - Life Safety	1 day	Thu 9/13/12	Thu 9/13/12
150	DOH Inspection - Nursing Division	10 days	Fri 9/14/12	Thu 9/27/12
151	Phase 5 Complete	0 days	Thu 9/13/12	Thu 9/13/12
152	Owner Move into Phase 5 Areas	10 days	Thu 9/13/12	Wed 9/26/12
153				
154	Final Site Grading	20 days	Mon 5/7/12	Fri 6/1/12
155	Site Concrete	20 days	Thu 6/7/12	Wed 7/4/12
156	Asphalt Paving	10 days	Mon 7/9/12	Fri 7/20/12
157	Landscaping	25 days	Thu 7/26/12	Wed 8/29/12
158	Patio Trellis & Columns	10 days	Mon 8/20/12	Fri 8/31/12
159				
160	Punch List & Close Out	20 days	Fri 8/31/12	Thu 9/27/12



Project: Project1 Date: Mon 10/3/11	Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline				
	Split	External Tasks	Inactive Summary	Manual Summary	Progress				
	Milestone	External Milestone	Manual Task	Start-only					
	Summary	Inactive Task	Duration-only	Finish-only					

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Appendix E

LEED Scorecard

LEED 2009 for Healthcare: New Construction and Major Renovations

Project Checklist

Project Name: Masonic Village at Sewickley

Date: 10/19/11

Y	?	N		Sustainable Sites	Possible Points: 18
Y	11				
Y	?	N			
Y			Prereq 1	Construction Activity Pollution Prevention	
Y			Prereq 2	Environmental Site Assessment	
		N	Credit 1	Site Selection	0
Y			Credit 2	Development Density and Community Connectivity	1
		N	Credit 3	Brownfield Redevelopment	0
Y			Credit 4.1	Alternative Transportation—Public Transportation Access	3
Y			Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Roon	1
		N	Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Ve	0
Y			Credit 4.4	Alternative Transportation—Parking Capacity	1
		N	Credit 5.1	Site Development—Protect or Restore Habitat	0
Y			Credit 5.2	Site Development—Maximize Open Space	1
Y			Credit 6.1	Stormwater Design—Quantity Control	1
Y			Credit 6.2	Stormwater Design—Quality Control	1
		N	Credit 7.1	Heat Island Effect—Non-roof	0
		N	Credit 7.2	Heat Island Effect—Roof	0
		N	Credit 8	Light Pollution Reduction	0
Y			Credit 9.1	Connection to the Natural World—Places of Respite	1
Y			Credit 9.2	Connection to the Natural World—Direct Exterior Access for Patie	1

Y	7			Water Efficiency	Possible Points: 9
Y			Prereq 1	Water Use Reduction—20% Reduction	
Y			Prereq 2	Minimize Potable Water Use for Medical Equipment Cooling	
Y			Credit 1	Water Efficient Landscaping—No Potable Water Use or No Irrig	1
Y			Credit 2	Water Use Reduction: Measurement & Verification	1
Y			Credit 3	Water Use Reduction	2
Y			Credit 4.1	Water Use Reduction—Building Equipment	1
Y			Credit 4.2	Water Use Reduction—Cooling Towers	1
Y			Credit 4.3	Water Use Reduction— Food Waste Systems	1

Y	20			Energy and Atmosphere	Possible Points: 39
Y			Prereq 1	Fundamental Commissioning of Building Energy Systems	
Y			Prereq 2	Minimum Energy Performance	
Y			Prereq 3	Fundamental Refrigerant Management	
Y			Credit 1	Optimize Energy Performance	18
		N	Credit 2	On-Site Renewable Energy	0
		N	Credit 3	Enhanced Commissioning	0
	?		Credit 4	Enhanced Refrigerant Management	0
Y			Credit 5	Measurement and Verification	2
		N	Credit 6	Green Power	0
		N	Credit 7	Community Contaminant Prevention—Airborne Releases	0

	6	N		Materials and Resources	Possible Points: 16
Y	?	N			
Y			Prereq 1	Storage and Collection of Recyclables	
	?		Prereq 2	PBT Source Reduction—Mercury	
		N	Credit 1.1	Building Reuse—Maintain Existing Walls, Floors, and Roof	0
		N	Credit 1.2	Building Reuse—Maintain Interior Non-Structural Elements	0
		N	Credit 2	Construction Waste Management	0
Y			Credit 3	Sustainably Sourced Materials and Products	1
Y			Credit 4.1	PBT Source Reduction—Mercury in Lamps	1
Y			Credit 4.2	PBT Source Reduction—Lead, Cadmium, and Copper	2
Y			Credit 5	Furniture and Medical Furnishings	1
Y			Credit 6	Resource Use—Design for Flexibility	1

Y	11			Indoor Environmental Quality	Possible Points: 18
Y			Prereq 1	Minimum Indoor Air Quality Performance	
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	
Y			Prereq 3	Hazardous Material Removal or Encapsulation	
Y			Credit 1	Outdoor Air Delivery Monitoring	1
Y			Credit 2	Acoustic Environment	1
Y			Credit 3.1	Construction IAQ Management Plan—During Construction	1
Y			Credit 3.2	Construction IAQ Management Plan—Before Occupancy	1
		N	Credit 4	Low-Emitting Materials	0
Y			Credit 5	Indoor Chemical and Pollutant Source Control	1
Y			Credit 6.1	Controllability of Systems—Lighting	1
Y			Credit 6.2	Controllability of Systems—Thermal Comfort	1
Y			Credit 7	Thermal Comfort—Design and Verification	1
Y			Credit 8.1	Daylight and Views—Daylight	2
Y			Credit 8.2	Daylight and Views—Views	1

	0	N		Innovation in Design	Possible Points: 6
		N	Prereq 1	Integrated Project Planning and Design	
		N	Credit 1.1	Innovation in Design: Specific Title	0
		N	Credit 1.2	Innovation in Design: Specific Title	0
		N	Credit 1.3	Innovation in Design: Specific Title	0
		N	Credit 1.4	Innovation in Design: Specific Title	0
	?		Credit 2	LEED Accredited Professional	0
		N	Credit 3	Integrated Project Planning and Design	0

	0	N		Regional Priority Credits	Possible Points: 4
		N	Credit 1.1	Regional Priority: Specific Credit	0
		N	Credit 1.2	Regional Priority: Specific Credit	0
		N	Credit 1.3	Regional Priority: Specific Credit	0
		N	Credit 1.4	Regional Priority: Specific Credit	0

Sil		55		Total	Possible Points: 110

Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110

- Courtesy of usgbc.org

Appendix F

Calculations & Tabulated Data

Design Criteria:

Hollow Core Floor Plank: 50 psf.

Beam Self-Weight: 3 psf.

Resident Room Live Load: 40 psf.

Factored Load = [1.2(50 psf.+3 psf.)] + (1.6 x 40 psf.) = 127.6 psf.

Tributary Area (A_t) = 25.5 ft. x 15 ft. = 382.5 ft^2

P_u = 127.6 psf. x 382.5 ft^2 = 48.8 Kip

V_u = 48.8 Kip/2 = 24.4 Kip

M_u = 48.8 Kip x 10 ft. = 488 K-ft.

No Brace Points: C_b = 1.14 (See Figure 41)

M_u' = M_u/C_b = 488/1.14 = 428.1

- W14x90 most efficient (See Figure 42)
- Shape exceed limit for flexure
- **Use W16x89** (See Figure 43)

FLEXURE:

WLB (Web Local Buckling):

E = 29,000 ksi

Fy = 50 ksi

h/t_w = 27.0 (See Figure 44)

$$\lambda_{pw} > \lambda_w$$

$$\lambda_{pw} = 3.76\sqrt{E/fy} > \lambda_w = h/t_w$$

$$3.76\sqrt{29{,}000/50} > 27.0$$

$$\mathbf{90.6 > 27.0} \quad \textbf{OK}$$

FLB (Flange Local Buckling):

$b_f/2t_f$ = 5.92 (See Figure 44)

$$\lambda_{pf} > \lambda_{fy}$$

$$\lambda_{pf} = 0.38\sqrt{E/fy} > \lambda_{fy} = b_f/2t_f$$

$$9.15 > 5.92$$

- Therefore $\phi M_n = \phi M_p$ = 656 K-ft (See Figure 43)
- $\phi M_p > M_u$
- **656 K-ft > 488 K-ft OK**

LTB (Lateral Torsional Buckling):

$L_B = 25.5$ ft.

$L_P = 8.8$ ft, $L_R = 30.2$ ft, $\phi B_f = 11.6$ (See Figure 43)

$L_B < L_R$ Therefore $\phi M_n = C_b[\phi M_p - \phi B_f (L_B - L_P)]$

$\phi M_n = 1.14[656 - 11.6(25.5 - 8.8)] = 527$ K-ft

$\phi M_n = 527$ K-ft $< \phi M_p = 656$, Therefore use ϕM_n

$\phi M_n > M_u$

527 K-ft > 488 K-ft OK

SHEAR:

a = ∞ (distance between web stiffeners)

a/h < 3 , Therefore Kv = 5

$h/t_w < 1.1\sqrt{(Kv * E)/fy}$

27.0 < 59.0 , Therefore $C_v = 1.0$

$h/t_w < 2.24\sqrt{E/fy}$

27.0 < 53.7 , Therefore $\phi = 1.0$

Area of Web (A_w) = 16.5 in. x 0.525 in. = 8.82 in^2

$\phi V_n = 0.6\phi F_y A_w C_v$

$\phi V_n = 0.6(1.0)(50\text{ ksi})(8.82\text{ in}^2)(1.0) = 264.6$ kip

$\phi V_n > V_u$

264.6 kip > 24.4 kip OK

Live Load Deflection:

w = 40 psf. x 15 = 600 plf = 0.05 k/in

L = 25.5 ft. x 12 in/ft. = 306 in

$I_x = 1{,}300\text{ in}^4$ (See Figure 43)

$\Delta_{MAX} < 5wL/384EI$ (See Figure 45)

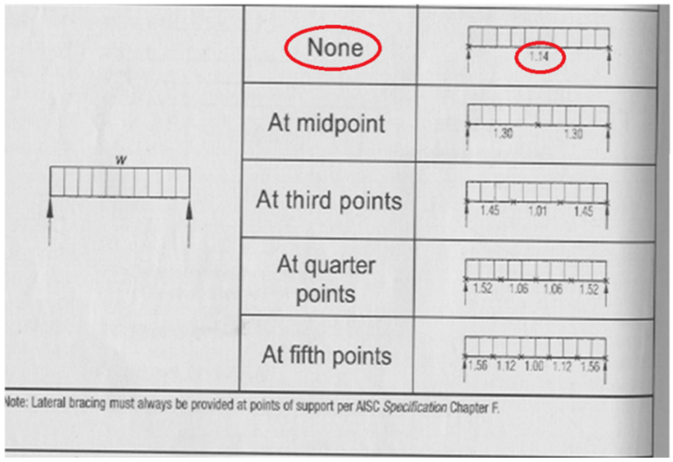
$\Delta_{MAX} = [5(0.05\text{ k/in})(306\text{ in})^4] / [384(29{,}000\text{ ksi})(1{,}300\text{ in}^4)] = 0.15$

L/360 = 306 in/360 = 0.85

$\Delta_{MAX} <$ L/360

0.15 < 0.85 OK

Steel Construction Manual: 14th Edition (Page 3-18)



(**Figure 41:** C_b Value)

Steel Construction Manual: 14th Edition (Page 3-123)

(**Figure 42:** Initial Wide Flange Selection)

Steel Construction Manual: 14th Edition (Page 3-24)

W24×76	200	499	750	307	462	15.1	22.6	6.78	19.5	2100	210	315
W16×100	198	494	743	306	459	7.86	11.9	8.87	32.8	1490	199	298
W21×83	196	489	735	299	449	13.8	20.8	6.46	20.2	1830	220	331
W14×109	192	479	720	302	454	5.01	7.54	13.2	48.5	1240	150	225
W18×86	186	464	698	290	436	9.01	13.6	9.29	28.6	1530	177	265
W12×120	186	464	698	285	428	3.94	5.95	11.1	56.5	1070	186	279
W24×68	177	442	664	269	404	14.1	21.2	6.61	18.9	1830	197	295
W16×89	175	437	656	271	407	7.76	11.6	8.80	30.2	1300	176	265
W14×99	173	430	646	274	412	4.91	7.38	10.5	45.3	1110	138	207
W21×73	172	429	645	264	396	12.9	19.4	6.39	19.2	1600	193	289
W12×106	164	409	615	253	381	3.93	5.89	11.0	50.7	933	157	236
W18×76	163	407	611	255	383	8.50	12.8	9.22	27.1	1330	155	232
W21×68	160	399	600	245	368	12.5	18.8	6.36	18.7	1480	181	272
W14×90	157	382	574	250	375	4.82	7.26	15.1	42.5	999	123	185

(**Figure 43:** Economical Beam that Fits in Plenum & Doesn't Exceed Flexural Limit)

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Nominal Wt.	Compact Section Criteria		Axis X-X				Axis Y-Y				r_{ts}	h_o	Torsional Properties	
	$\frac{b_f}{2t_f}$	$\frac{h}{t_w}$	I	S	r	Z	I	S	r	Z			J	C_w
lb/ft			in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	in.	in.^{3}	in.	in.	in.^{4}	in.^{6}
100	5.29	24.3	1490	175	7.10	198	186	35.7	2.51	54.9	2.92	16.0	7.73	11900
89	5.92	27.0	1300	155	7.05	175	163	31.4	2.49	48.1	2.88	15.9	5.45	10200
77	6.77	31.2	1110	134	7.00	150	138	26.9	2.47	41.1	2.85	15.7	3.57	8590
67	7.70	35.9	954	117	6.96	130	119	23.2	2.46	35.5	2.82	15.6	2.39	7300
57	4.98	33.0	758	92.2	6.72	105	43.1	12.1	1.60	18.9	1.92	15.7	2.22	2660
50	5.61	37.4	659	81.0	6.68	92.0	37.2	10.5	1.59	16.3	1.89	15.7	1.52	2270
45	6.23	41.1	586	72.7	6.65	82.3	32.8	9.34	1.57	14.5	1.87	15.5	1.11	1990
40	6.93	46.5	518	64.7	6.63	73.0	28.9	8.25	1.57	12.7	1.86	15.5	0.794	1730
36	8.12	48.1	448	56.5	6.51	64.0	24.5	7.00	1.52	10.8	1.83	15.5	0.545	1460

(**Figure 44:** Compact Section Criteria for W16x89)

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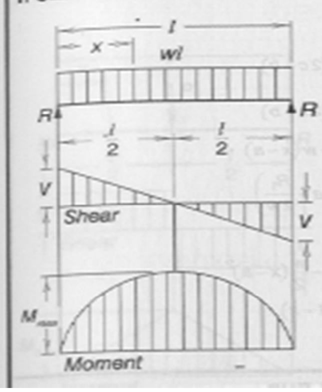
Table 3-23
Shears, Moments and Deflections

1. SIMPLE BEAM — UNIFORMLY DISTRIBUTED LOAD



Total Equiv. Uniform Load .... $= wl$

$R = V$ .... $= \frac{wl}{2}$

V_x .... $= w\left(\frac{l}{2} - x\right)$

M_{max} (at center) .... $= \frac{wl^2}{8}$

M_x .... $= \frac{wx}{2}(l - x)$

Δ_{max} (at center) .... $= \frac{5wl^4}{384EI}$

Δ_x .... $= \frac{wx}{24EI}(l^3 - 2lx^2 + x^3)$

(**Figure 45:** Δ_{MAX} for Uniformly Distributed Load)

(**Table 18:** Mortar-Sand Mixing Ratios)

Approximate quantities of mortar and sand required for laying 1,000 concrete blocks 3/8" Joints 1:3 mix by Volume (Face Shell Mortar Bed)

Block Size	Wall Thickness	Cu. Ft. Mortar	Sacks Mortar	Tons Sand
4x8x16"	4	75	25	3
8x5x12"	8	75	25	3
8x8x16"	8	75	25	3
8x12x16"	12	75	25	3

10% allowance made for waste. All joints are full bed mortar.

- Courtesy of Old Castle